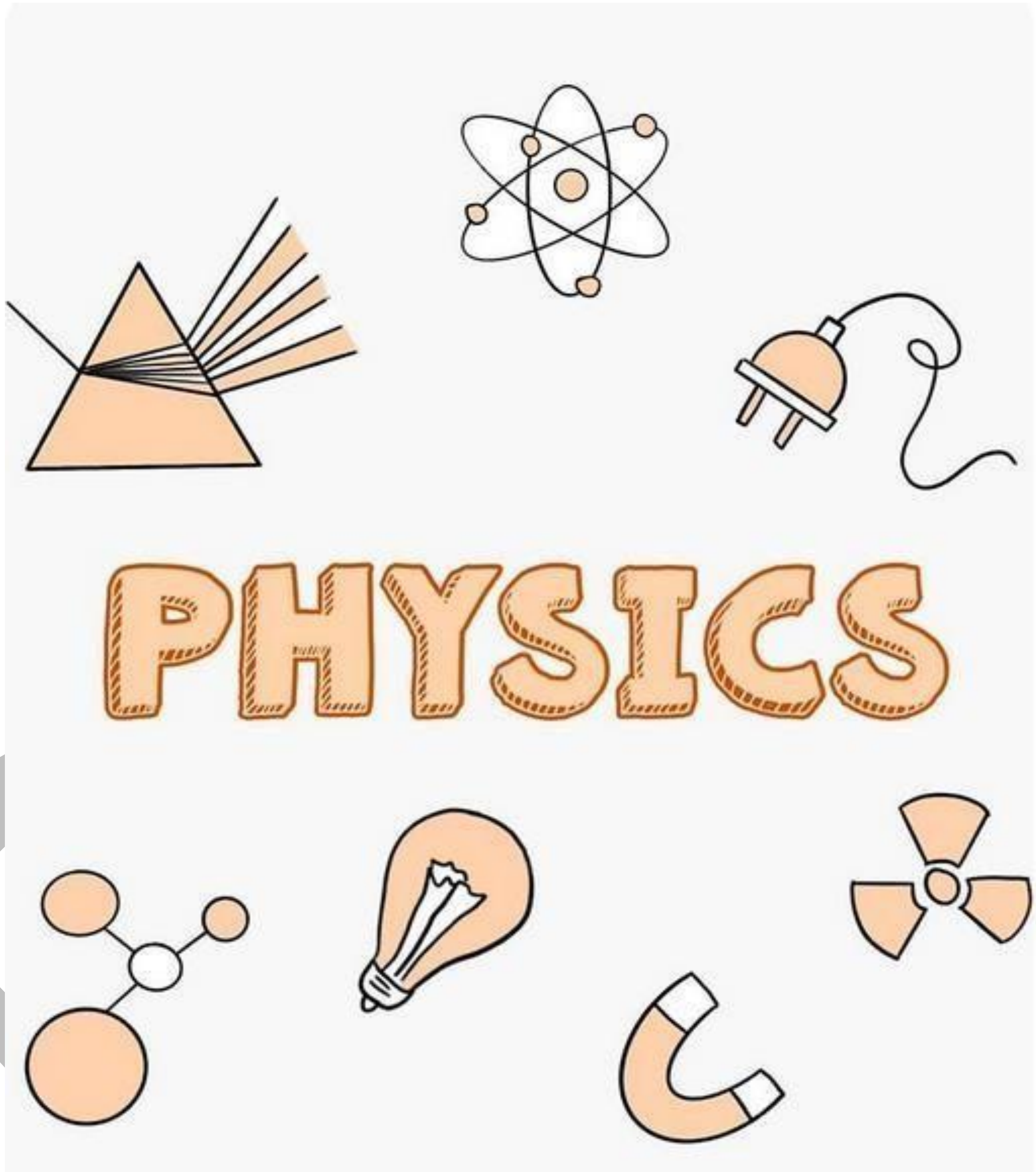


Name: …………………………………

Class: ……………………………….

Important physical and mathematical basics:

1-some unit's conversion:

Factor	10^{-9}	10^{-6}	10^{-3}	10^{-2}	10^{3}	10^{6}	10^{9}
Prefix	nano	Micro	Milli	Centi	Kilo	Mega	Giga
Symbol	n	µ	m	c	K	M	G

- **Area**

$cm^2 \xrightarrow{10^{-4}} m^2$

$mm^2 \xrightarrow{10^{-6}} m^2$

- **Volume**

$cm^3 \xrightarrow{10^{-6}} m^3$

$mm^3 \xrightarrow{10^{-9}} m^3$

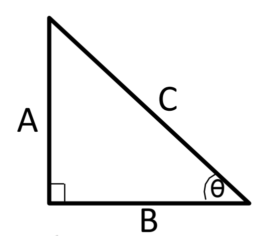
$cm^3 \xrightarrow{10^{-3}} Liter$

$Liter \xrightarrow{10^{-3}} m^3$

- **Pythagoras theorem**

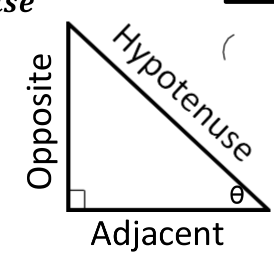
In the right angle triangle the square of hypotenuse is equal to the sum of squares of the other two sides

i.e $\boxed{C^2 = A^2 + B^2}$ **so** $\boxed{C = \sqrt{A^2 + B^2}}$



Sin θ $= \frac{Opposite}{Hypotenuse}$, Cos θ $= \frac{Adjacent}{Hypotenuse}$

Tan θ $= \frac{Opposite}{adjacent}$



Unit One

Chapter 1: Wave motion

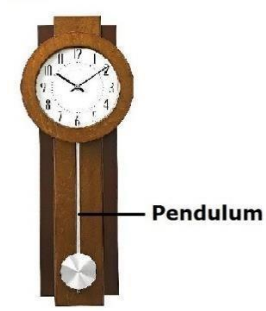
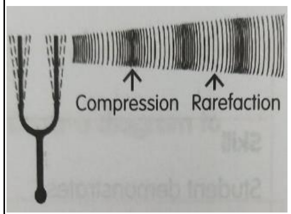
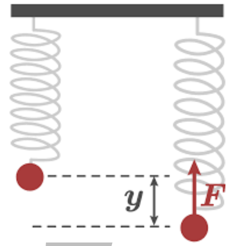
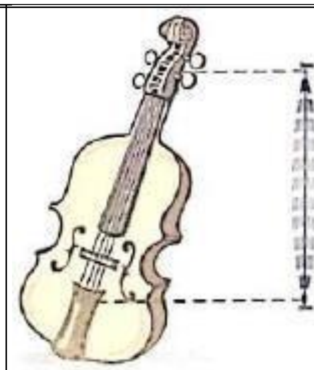
Lesson 1: Oscillatory motion

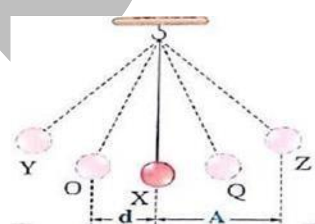
You have studied that motion can be classified into two types :

Translation motion	Periodic motion

Oscillatory motion:

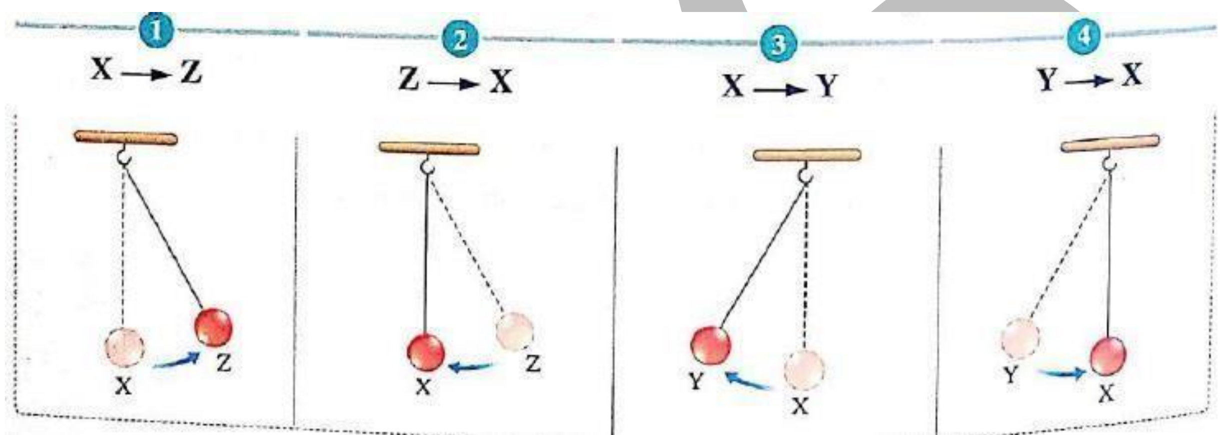
It is the motion of a vibrating body about its rest position or its equilibrium position that gets repeated through equal intervals of time.

			
Simple pendulum (Clock pendulum)	Vibrating tuning fork	Plumb or bob suspended to a spring (yoyo)	Vibrating string Violin strings

The diffrence between Displacement & Amplitude	
	
1) Displacement	**2) Amplitude**

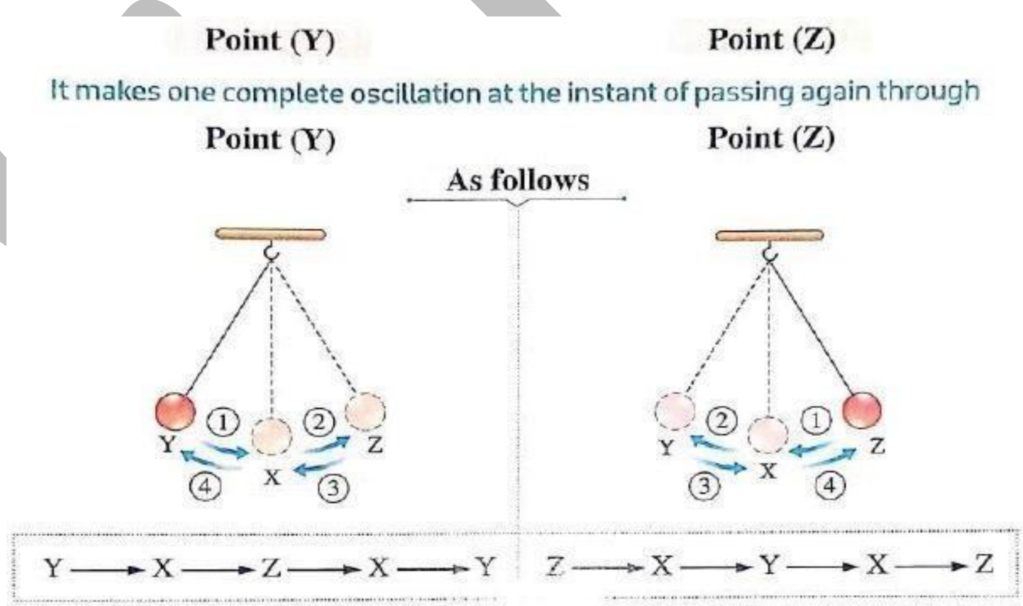
3) Complete oscillation

When observing the motion of the pendulum bob starting from point X in a certain direction until it returns back to the same point again moving in the same direction, so the pendulum has made a complete oscillation where its path of motion can be represented as follows:



Hence, the pendulum bob passes by point X two successive times in the same direction with the same velocity, i.e. **(body has the same phase).**

If the motion of the body has been observed starting from:



- **Complete Oscillation:**

It is the motion of an oscillating body during a period of time when it passes through a certain point in its path of motion two successive times in the same direction.

	The periodic time (T)	The frequency (P)
Definition		
Mathematical Relation		
The measuring Unit		

The graphically representation between (N) Vs (T)

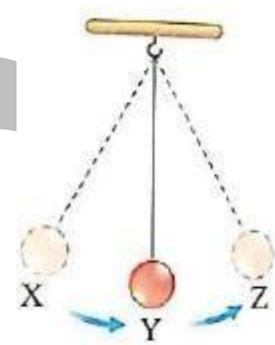
The graphically representation between (P) vs (T) & ($\frac{1}{T}$)

Simple harmonic motion (SHM)

Simple harmonic motion is a type of periodic motion such as the motion of a simple pendulum or a body fixed to a spring coil which can be represented by a sinusoidal curve (sine wave).

Example 1: In the opposite figure: If the time taken by the pendulum to move from X to Z is 0.8 s, calculate:

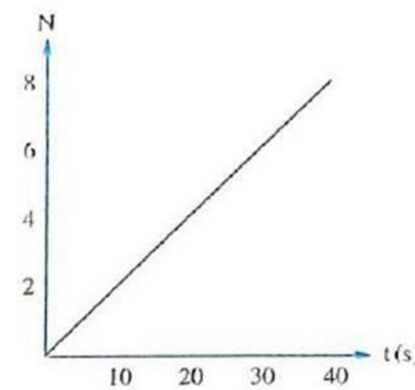
(a) The periodic time.
(b) The frequency.
(c) The number of complete oscillations through 16 s.
(d)The time required to make 50 oscillations.



Solution:

Example 2:

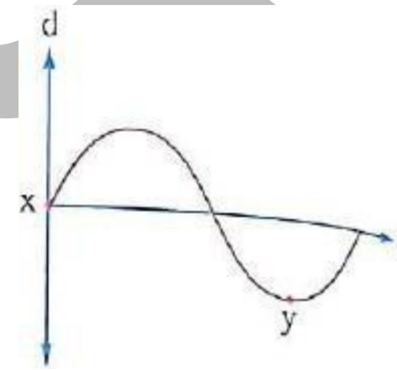
The opposite graph represents the relation between the number of complete oscillations (N) and the time (t), then the frequency of motion of this body equals ....

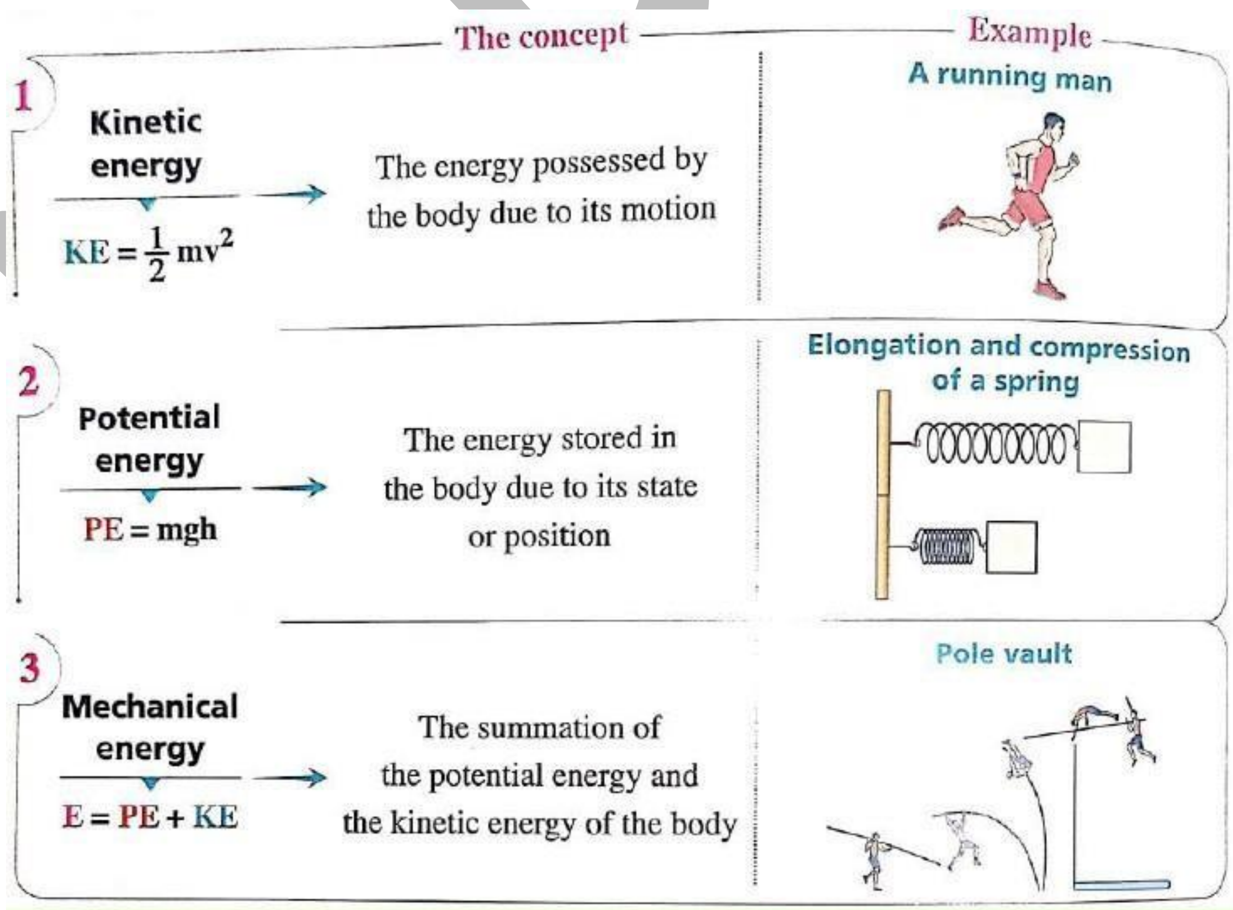


Solution:

Example 4:

The opposite graph represents the relation between the displacement (d) and the time (t) for a mass tied to a spring and vibrating with frequency 60 Hz, then the time taken by the mass to pass between the two points x, y is …………………

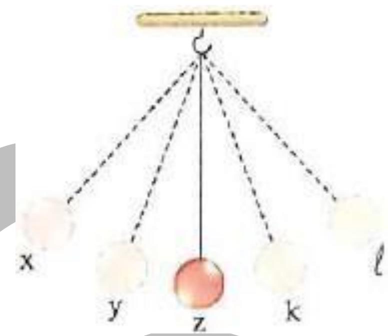




	The concept		Example
1	Kinetic energy $KE = \frac{1}{2}mv^2$	The energy possessed by the body due to its motion	A running man
2	Potential energy $PE = mgh$	The energy stored in the body due to its state or position	Elongation and compression of a spring
3	Mechanical energy $E = PE + KE$	The summation of the potential energy and the kinetic energy of the body	Pole vault

Example 5:

The opposite figure shows the motion of a simple pendulum where xy = yz = zk = kl. If the pendulum takes time (t) to move from x to y. the periodic time is...........



a) 8t b) less than 8t

c) greater than 8t d) indeterminable

Exercise 1

Choose the correct answer:

1) The motion of a body in a circular path with a constant speed is considered…………

(a) a periodic motion (b) a simple harmonic motion

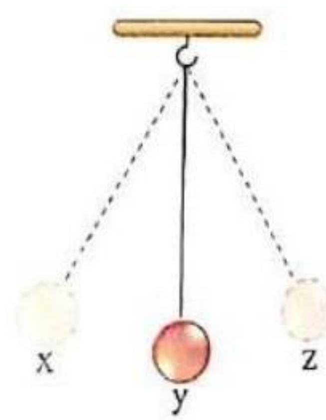
(c) an oscillatory motion (d) a wave motion

2) The motion of a swing is considered……….

(a) a translational motion (b) a wave motion

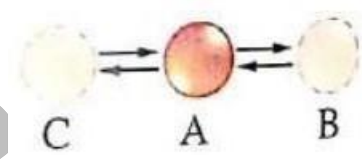
(c) an oscillatory motion (d) a circular motion

3) In the opposite figure, the pendulum makes a complete oscillation when it moves from ....



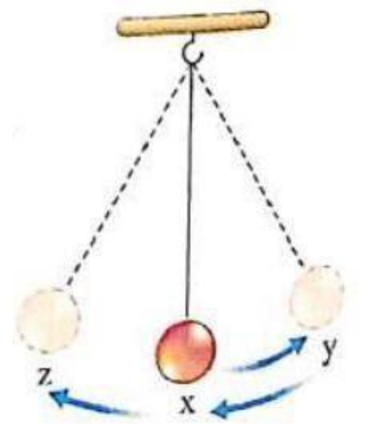
(a) $x \longrightarrow y$
(b) $x \longrightarrow y \longrightarrow z$
(c) $x \longrightarrow y \longrightarrow z \longrightarrow y$
(d) $x \longrightarrow y \longrightarrow z \longrightarrow y \longrightarrow x$

4) In the opposite figure, a body moves in an oscillatory motion, so the distance which is moved by the body during a complete oscillation equals ....



(a) double the distance AB.
(b) half the distance AC.
(c) double the distance BC.
(d) four times the distance BC.

5) The opposite figure shows a simple pendulum vibrating with an amplitude.
A. If its bob has moved from position x to position y and then to position z, the magnitude of displacement of the pendulum bob equals............

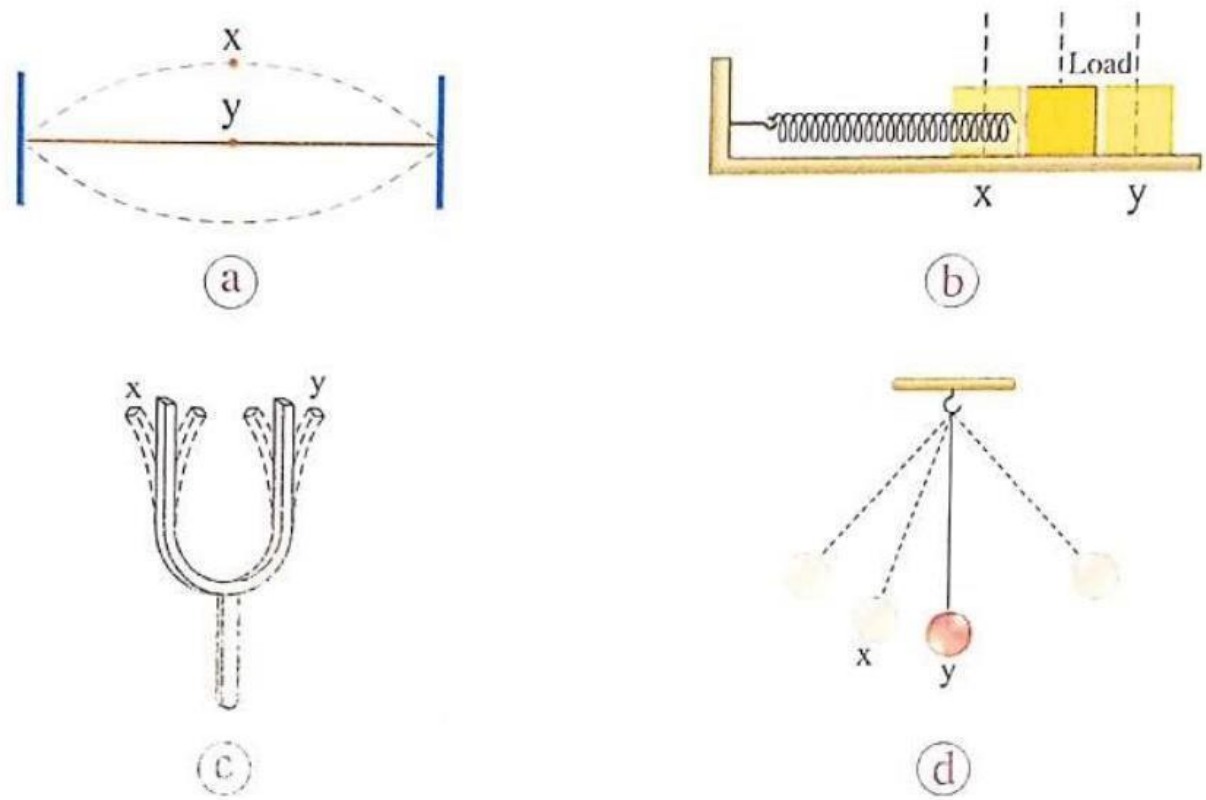


(a) A
(b) 2A
(c) 3A
(d) zero

6)In an oscillatory motion, the ratio between the time of an amplitude and the time of a complete oscillation is..........

(a) 2 (b) $\frac{1}{2}$ (c) 4 (d) $\frac{1}{4}$

7)In which of the following figures is the distance between the two positions x, y representing the amplitude of vibration?



8) The opposite figure shows a string vibrating with a periodic time T, so the time taken by the string reaches the maximum displacement from its equilibrium position is ....

(a) T/4 (b) T/3 (c) T/2 (d) T

9)The periodic time of an oscillating simple pendulum is the time taken by the pendulum bob to pass two successive times through a point in its path when this point is………….

(a) at the equilibrium position.

(b) at the maximum displacement away from the equilibrium position.

(c)between the equilibrium position and the maximum displacement in the positive direction.

(d)between the equilibrium position and the maximum displacement in the negative direction.

10) The opposite figure shows a person measuring his pulse rate which is found to be 75 beats per minute.

What is the frequency and the periodic time of his heart muscle motion?

	The frequency	The periodic time
a	0.8 Hz	0.8 s
b	0.8 Hz	1.25 s
c	1.25 Hz	0.8 s
d	1.25 Hz	1.25 s

Lesson 2: Wave motion

What Happens when a stone is dropped in a lake?

The wave:

It is a disturbance that propagates and transfers energy in the

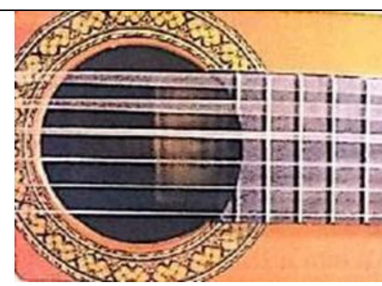
Types of waves:

1. Mechanical waves
2. Electromagnetic waves

First Mechanical waves:

Mechanical waves are produced due to the vibration of a body in a medium, so the vibration (disturbance) propagates from the body through the medium.

- Source: They need a medium through which they can propagate.
- Examples:

		
Water waves	Sound waves	Waves that propagate in strings during their vibrations

- Conditions of obtaining mechanical waves:

1. The existence of a vibrating source
2. The occurrence of a disturbance that transfer from the source to the medium
3. The existence of a medium to transmit the disturbance

Note:

Since sound is a mechanical wave, it cannot propagate in empty space, so:

-The sounds of cosmic explosions that happen in the outer space cannot be heard.

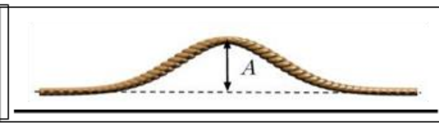
- Astronauts use wireless devices to communicate in space.

Types of Mechanical waves:

1- Transverse waves

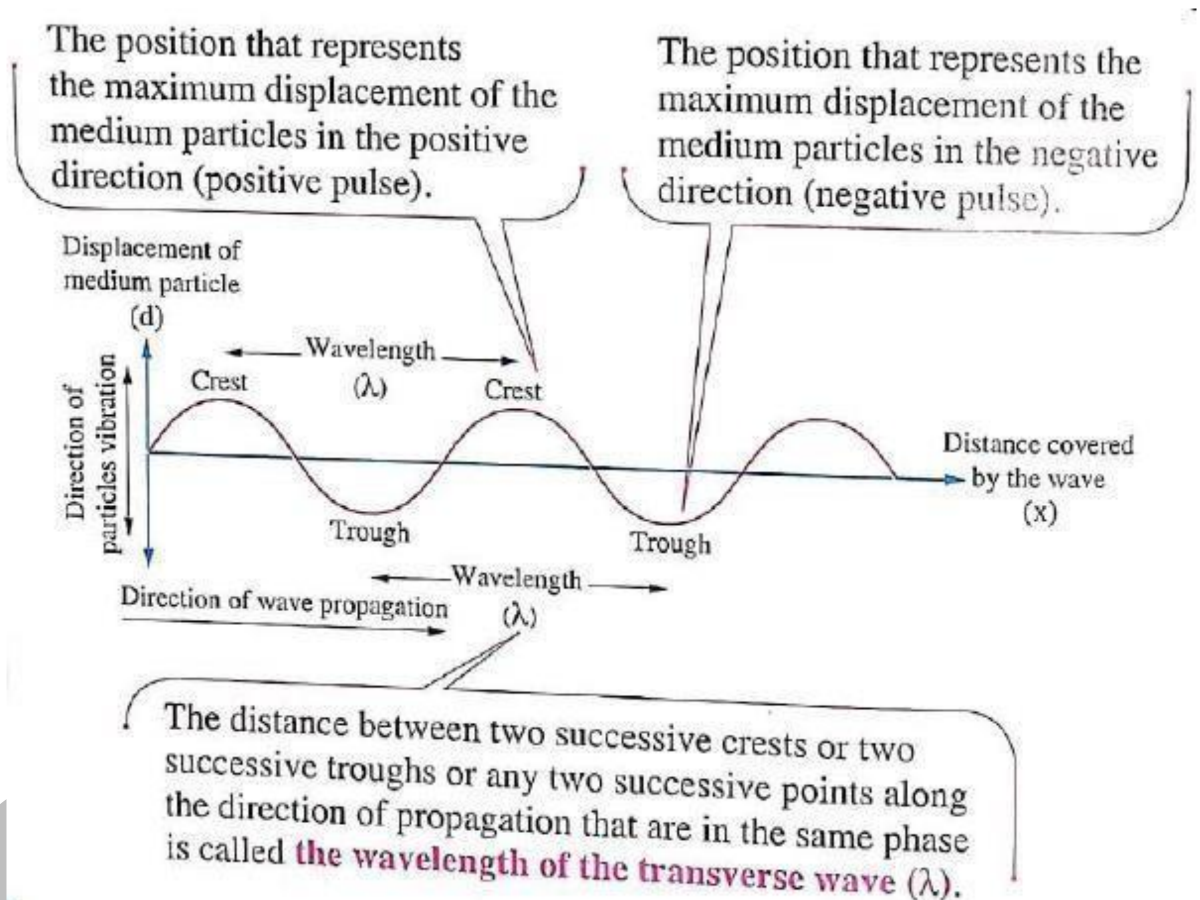
2- Longitudinal waves

(1) transverse wave: It is a wave in which the directions of medium particles vibrations about their equilibrium positions are perpendicular to the direction of wave propagation.

A pulse: Is a single disturbance in a form of half wave	

Note that:

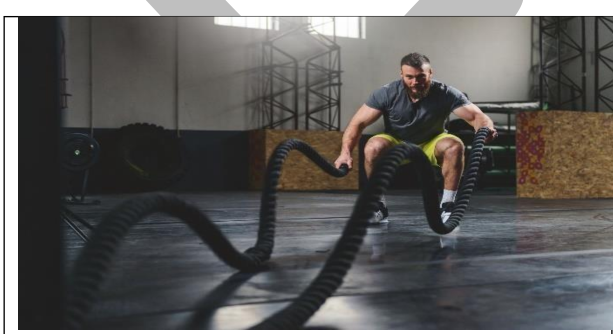
The distance between two successive crests or two successive troughs or any two successive points along the direction of propagation that are in the same phase is called the wavelength of the transverse wave (λ).



<u>Notice that:</u>

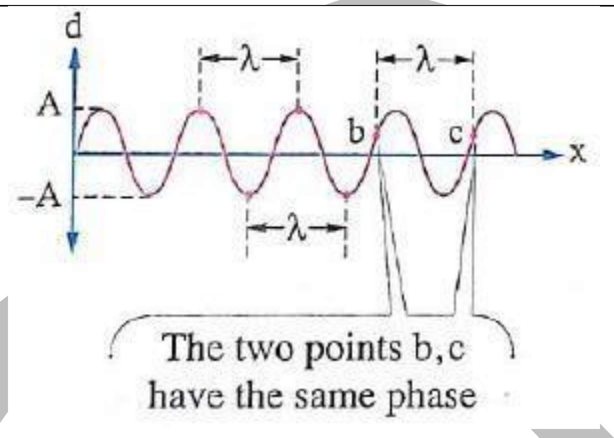
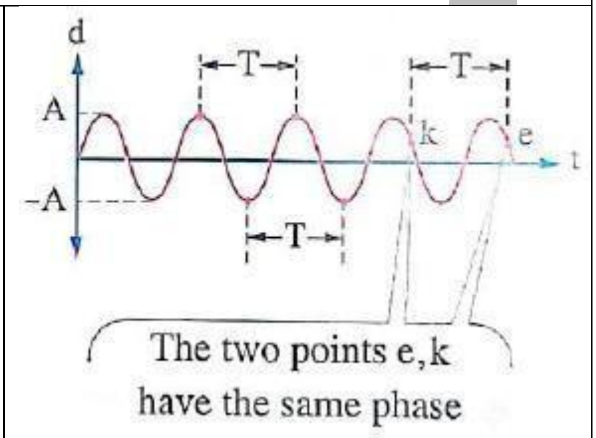
A medium particle has the same phase at a definite position, when it passes through that position two successive times with the same velocity (including magnitude & direction).

<u>Examples of transverse waves</u>:

Graphical representation of transverse waves:

The motion of the particles of the medium in which the transverse wave propagates can be represented through the graphs of:

The displacement of the particles of the medium (d) versus the horizontal distance (x) covered by the wave at a certain instant.	The displacement of one of the medium particles (d) versus time (t).
We get a sine curve	
	
From the two graphs, we find	
Wave length (λ)= $\frac{x\,(\boldsymbol{Total\ distance})}{\boldsymbol{N(Number\ of\ waves)}}$	Frequency(P) = $\frac{\boldsymbol{N(Number\ of\ waves)}}{\boldsymbol{t(Time\ in\ seconds)}}$ Frequency(P) = $\frac{\mathbf{1}}{\boldsymbol{T}}$

From the previous, we can define the wave amplitude (A) as follows:

The wave amplitude (A):

It is the maximum displacement of the vibrating medium particles away from their equilibrium positions.

Example 1:

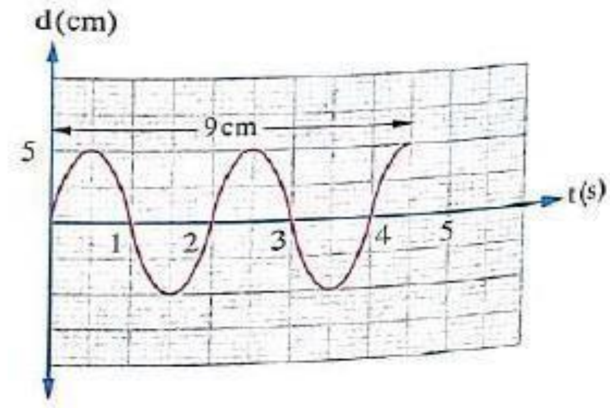
The opposite graph represents a transverse wave, calculate:

a) the amplitude

b) the frequency

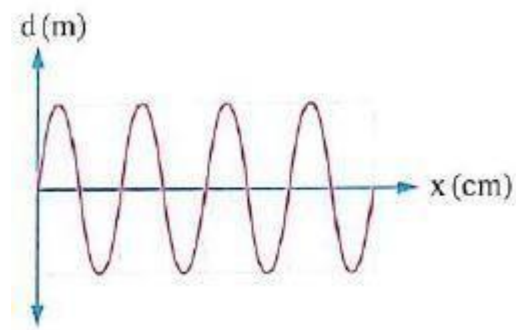
C) The periodic time

d) the wave length



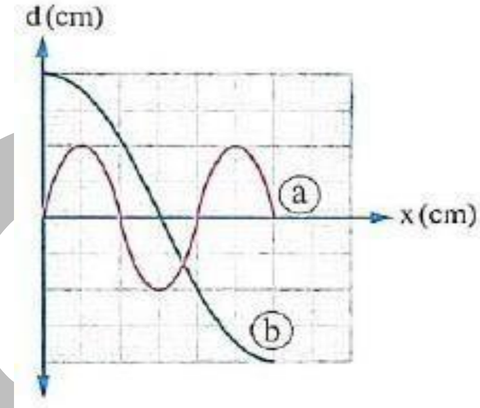
Solution:

The opposite graph represents the relation between the displacement (d) of the medium particles and the distance (x) travelled by two transverse waves is travelling at a certain instance and the distance (x) travelled by the wave, if the distance between the first trough and the seventh crest is 5.5 cm, the wavelength of the wave equals?



<u>Example 3:</u>

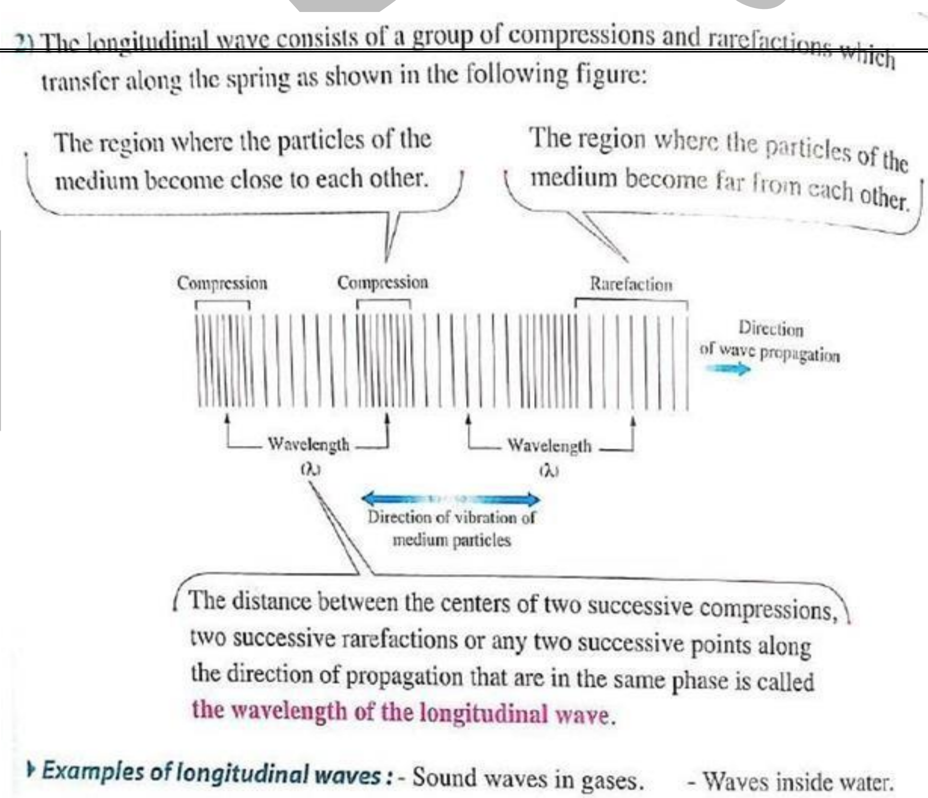
The opposite graph represents the relation between the displacement (d) of the medium particles and the distance (x) travelled by two transverse waves (a),(b), so the ratio between their wavelengths ($\frac{\lambda a}{\lambda b}$) equals?



2- <u>Longitudinal waves:</u>

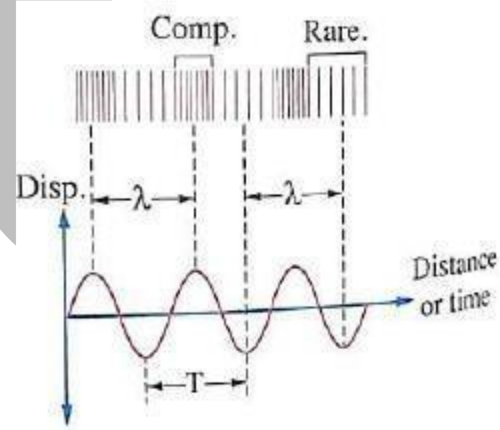
To describe the nature of longitudinal waves, we carry out the following experiment:

2) The longitudinal wave consists of a group of compressions and rarefactions which, transfer along the spring as shown in the following figure:



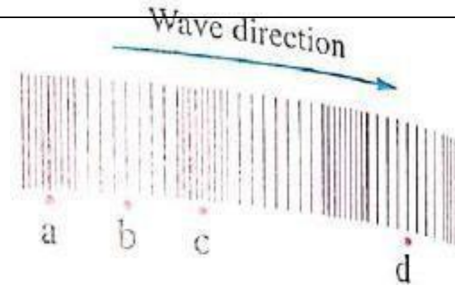
The graphical representation of longitudinal waves:

When we plot the relation between the displacement of the medium particles and the distance travelled by the wave at a certain instant or between the displacement and the time for the motion of the medium particles in which the longitudinal wave propagates, we get a sine wave curve as shown in the opposite figure, hence all the concepts and the laws of the transverse wave are applicable to this curve.



From the previous, we can compare between the two types of mechanical waves (Transverse & longitudinal) as follows:

Example 4:



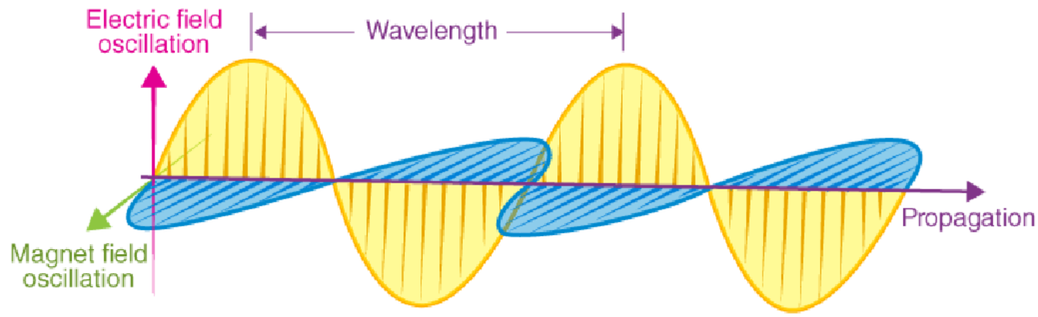
The opposite figure represents a longitudinal wave. If the distance between the two points a and b is I.7 m and the time:

taken by the wave to travel from c to d is 0.015 s. calculate

(a) The wavelength of the longitudinal wave.

(b) The frequency of the wave.

<u>Second: Electromagnetic waves:</u>



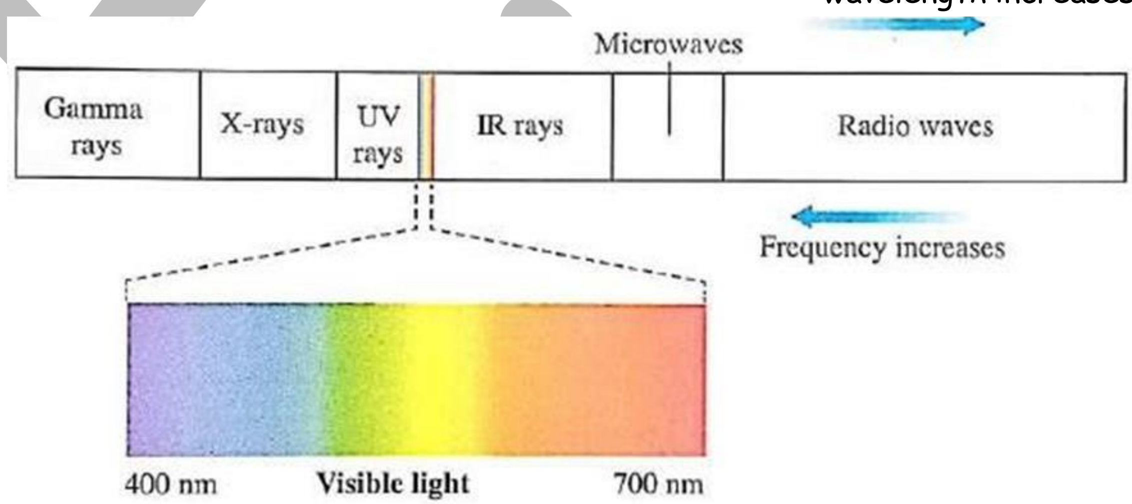
Concept: They are waves that originate from the vibration of electric and magnetic fields with the same frequency where both fields are in the same phase perpendicular to each other and to the direction of their propagation.

Propagation: They travel either in physical media or in empty space where their speed in space reaches its maximum constant value that equals 3×10^8 m/s.

Types: Transverse waves only.

<u>Electromagnetic spectrum:</u>

wavelength increases



From the previous, we can compare between mechanical and electromagnetic waves as follows:

Deducing the speed of propagation of the waves:

- If a wave has travelled a distance x through a time interval t, the speed of the wave (v) is calculated from the relation v= $\frac{x}{t}$

So, if the distance equals its wavelength (λ) then the wave takes a time equals to the periodic time (T)

So $$\boxed{V = \frac{\lambda}{T}}$$

But $P = \frac{1}{T}$ SO $$\boxed{V = \lambda \vartheta}$$

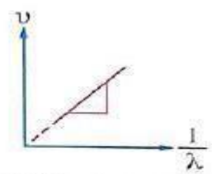
This equations is applicable to all types of waves (mechanical or electromagnetic)

The factors that affect the speed of wave in a medium:

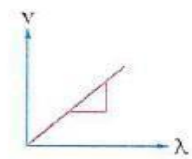
i.e.

- The wavelength is inversely proportional to the frequency (υ) at constant wave speed (v).
- The wavelength is directly proportional to the wave speed (v) at constant frequency (υ).

Graphical representation



$$\text{Slope} = \frac{\Delta \upsilon}{\Delta(\frac{1}{\lambda})} = v$$



$$\text{Slope} = \frac{\Delta v}{\Delta \lambda} = \upsilon$$

Notes:

- When applying the relation of $v = \lambda \upsilon$ on:

Two waves of the same type propagating in the same medium

The speed of the two waves will be the same because the wave speed depends only on the medium type.

$$v_1 = v_2$$

$$\lambda_1 \upsilon_1 = \lambda_2 \upsilon_2$$

$$\therefore \boxed{\frac{\lambda_1}{\lambda_2} = \frac{\upsilon_2}{\upsilon_1}}$$

Where

λ_1 and υ_1 are the wavelength and the frequency of the first wave, λ_2 and υ_2 are the wavelength and the frequency of the second wave.

A wave travelling from one medium to another

The frequency of the wave remains constant because the wave frequency depends on the source frequency.

$$\upsilon_1 = \upsilon_2$$

$$\frac{v_1}{\lambda_1} = \frac{v_2}{\lambda_2}$$

$$\therefore \boxed{\frac{\lambda_1}{\lambda_2} = \frac{v_1}{v_2}}$$

Where

λ_1 and v_1 are the wavelength and the speed in the first medium, λ_2 and v_2 are the wavelength and the speed in the second medium.

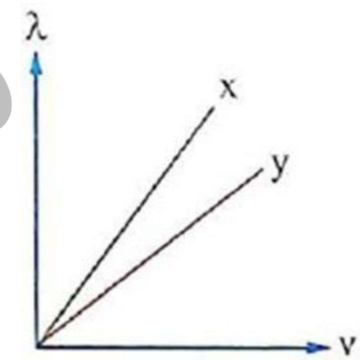
Example 5: A sound wave of wavelength λ propagates in air with a speed of330 mls, if it has travelled to another medium in which its speed is 990 mls, then its wavelength increases by ....

Example 4:

Two tones, whose frequencies are 340 Hz and 212Hz, travel in air. If the wavelength of one of them is longer than the other by 60 cm, then the speed of sound in air equals............

a) 337.9 m/s b) 430 m/s c) 342.1 m/s d) 343.2 m/s

Example 5: The opposite graph represents the relation between the wavelength (λ) for two waves (x, y) propagating in different media and the speed (v) of these two waves in each of these media, so which of the following relations is correct?



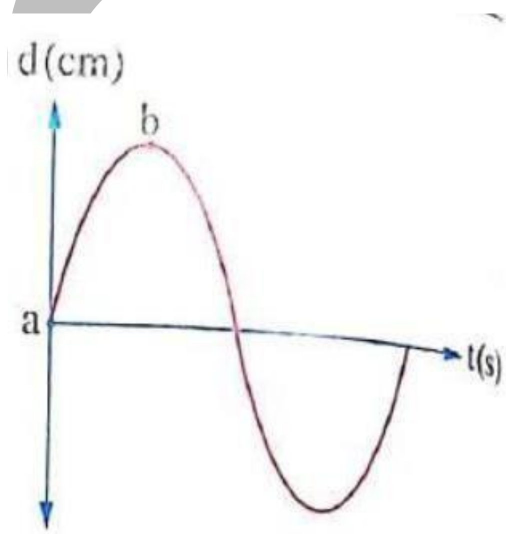
a) Tx < Ty b) Tx > Ty c) Px > Py d) Px = Py

Solution:

Exercise2

Choose the correct answer:

1) The opposite figure represents the relation between the vertical displacement (d) of one of the medium particles and the time (t) for a transverse wave of frequency that equals 50 Hz, then the time interval taken by the medium particle to move between the two points a and b is………….

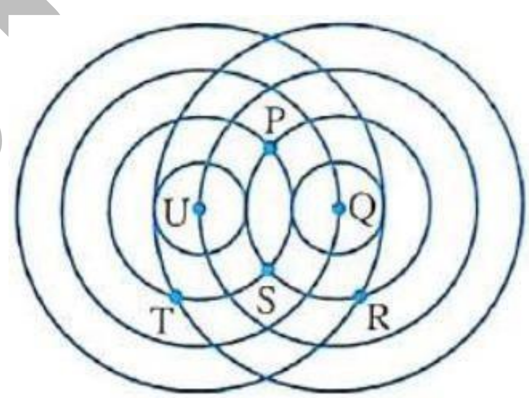


(a) 2/25 s
(b) 1/25 s
(c) 1/50 s
(d) 1/200 s

2) Waves transfer …………… in the direction of their propagation.

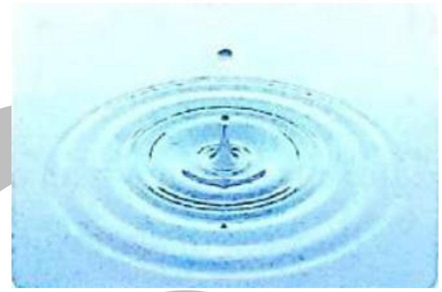
(a) matter
(b) particles
c) energy
d) water

3) Two waves interfere on the surface of the water as shown in the opposite figure, which two points in the figure represent the sources of these waves?



(a) P, S
(b) T, R
(c) Q, T
(d) U, Q

4) The opposite figure shows a wave propagating on the surface of a still lake, so this wave propagates in ....



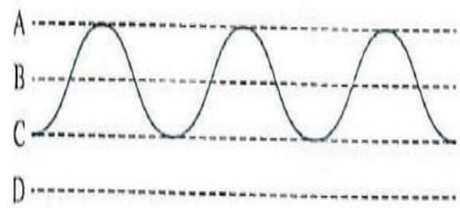
a) one direction with an increasing speed

b)Two opposite directions with two different speeds

c) all directions with the same speed

d) all directions with increasing speed

5) A train of waves passes on the water surface of a lake as shown in the opposite figure.

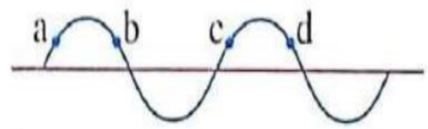


What will be the level at which the surface of water settles after the waves finish passing?

(a) A (b) B

(c) C (d) D

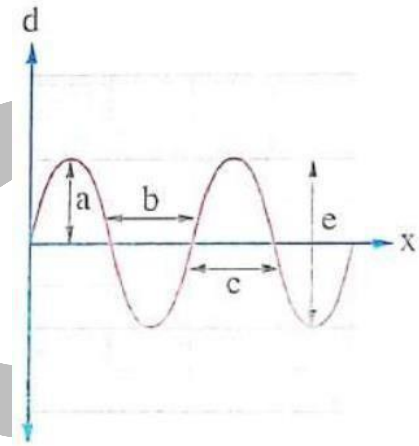
6) In the opposite wave, which of the points a, b, c, and d have the same phase?



a) a, b, c b) a, b

c) b, c d) b, d

7) The opposite graph represents the relation between the displacement (d) of the particles of a medium in which a transverse wave propagates with frequency (P), amplitude A, and the distance (x) traveled by the wave, if:



(i) The frequency of the wave is doubled at constant amplitude, then distance…………

(a) a increases to the double

(b) b increases to the double

(c) c decreases to its half

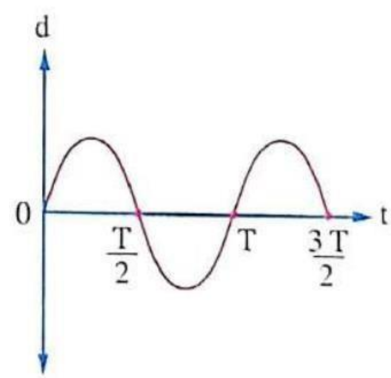
(d) e decreases to its half

ii) The amplitude of the wave is doubled at a constant frequency, then distance……..

(a) a decreases to its half (b) b decreases to its half

(c) c increases to the double (d) e increases to the double

8) A transverse wave propagates in a rope where the opposite graph of displacement (d) versus time (t) represents the motion of one of the rope particles, so what is the time required for this particle to return back to the same phase?



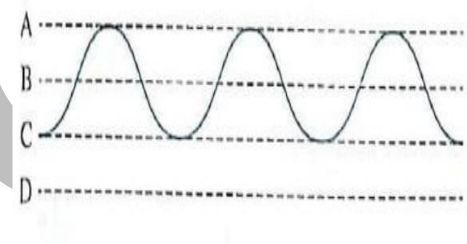
(a) T/2 (b) T/4

(c) T (d) 3/2 T

9)If the wavelength of a transverse wave is y, then the distance between the first crest and the crest of order n equals……..

(a) ny (b) (n + 1)y (c) (n -1) y (d) (n-1/2) y

10)In the opposite wave, if the distance between the first crest and the fifth trough is 140 cm, then the wavelength for this wave equals.........



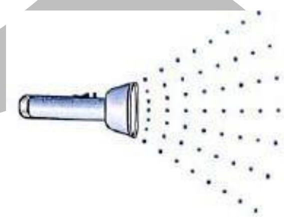
(a) 10 cm (b) 20 cm
(c)40 cm (d) 70 cm

Chapter 2: Properties of light

(Propagation, Reflection & Refraction)

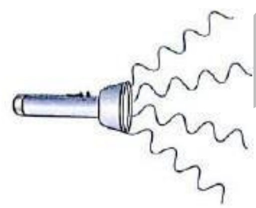
In the study of the nature of light, physicists were divided into two groups:

The first: (Isaac newton's idea)



Which considers light as very tiny particles.

The second: (Huygen's idea)



Which considers light as wave.

However, modern physics (quantum physics) has proven the principle of dual mature of light, which states that the electromagnetic radiation has:

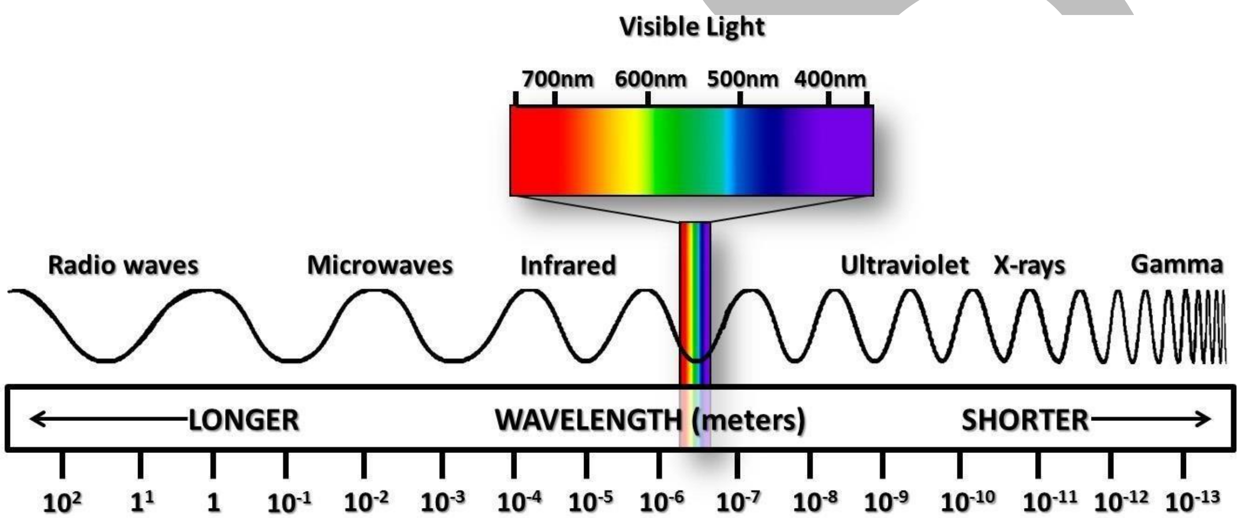
1- Wave nature: They are transverse electromagnetic waves.

2. Particle nature: They consist of energy quanta that have particle nature called photons.

Electromagnetic waves have an extensive range of frequencies and wavelength, this range is called:

The electromagnetic spectrum which includes:

Radio waves, Micro waves, Infrared, Visible light, Ultraviolet, X-rays & gamma rays

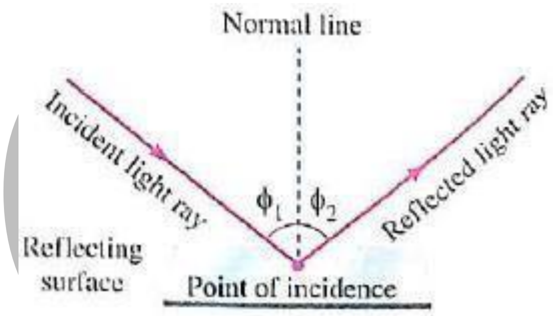


From the figure, it is clear that visible light is a limited part of the electromagnetic spectrum and in the following, we will study some of its properties:

1 Reflection
2 Refraction
3 Interference
4 Diffraction

first light reflection:

Occurrence: When light waves fall in a medium on a reflecting surface, they bounce back in the same medium and this phenomenon is known as **light reflection.**



Light reflection, angle of incidence and angle of reflection can be defined as follows:

1 Light reflection:

It is the bouncing of light waves in the same medium when they encounter a reflecting surface.

2 The angle of incidence:

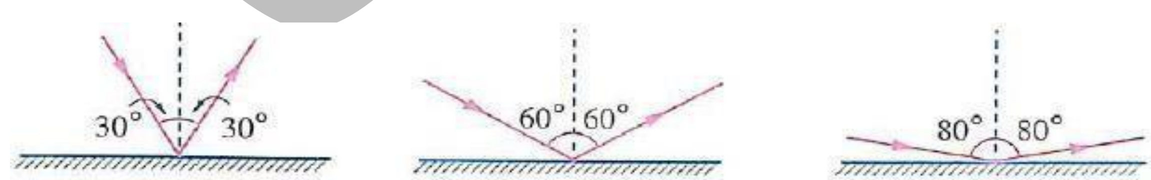
It is the angle between the **incident light** ray and the normal line on the reflecting surface at the point of incidence.

3 The angle of reflection:

It is the angle between the **reflected light** ray and the normal line on the reflecting surface at the point of incidence.

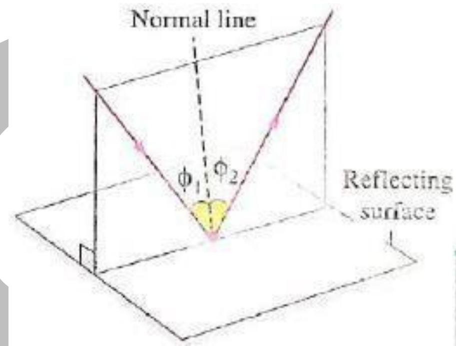
The reflection of light obeys two laws, which are:

1- Angle of incidence (=) Angle of reflection



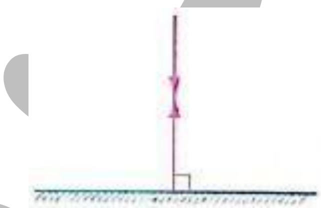
The second law:

The incident light ray, the reflected light ray and the normal line at the point of incidence all lie in the same plane which is perpendicular to the reflecting surface.

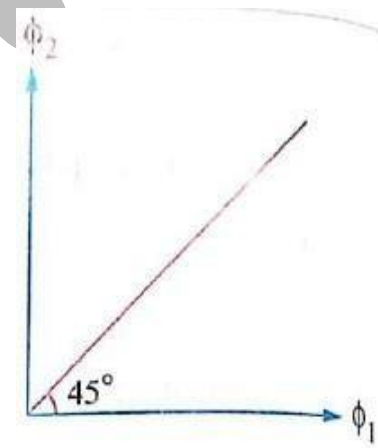


Notes:

2) The light ray which falls perpendicular to a reflecting surface gets reflected on itself Because the **angle of incidence equals** the **angle of reflection equal zero**



3) When plotting the relation between the angle of reflection (ø2) and the angle of incidence (ø1). we get a straight line and when the two axes have the same drawing scale, the straight line will make a 45° angle with the horizontal axis as in the opposite graph

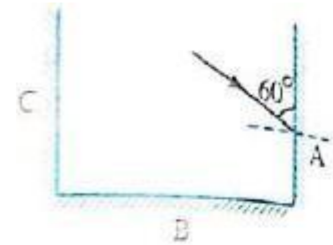


4) It is easier to see your reflected image on the glass window of a lighted room at night when the outside is dark than seeing your reflected image at daytime explain??

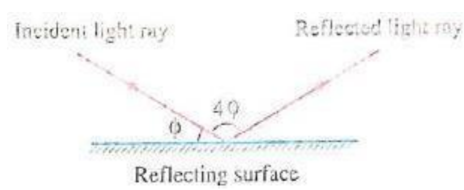
Because

Example 1:

Three mirrors; A.B and C, are perpendicular to each other. If a light ray falls on mirror A as shown in the figure trace the path of the light ray until its reflection at mirror C



Example 2:

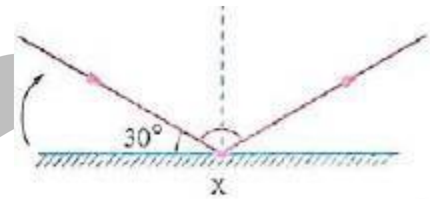


In the opposite figure calculate the angle of reflection.

Solution:

Example 3:

If the mirror gets rotated about point x in the direction shown in the figure by an angle of 10, the angle between the incident ray and the reflected ray becomes...........



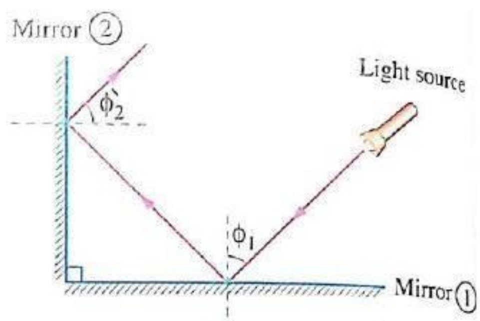
a) 140° b) 135°

c) 125° d) 15°

Solution:

Example 4:

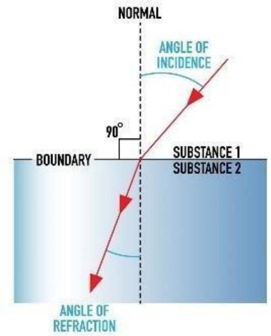
In the opposite figure, if the position of the light source is changed such that the angle of incidence (Ø1) increases by 5°,the angle Ø2` , will ....

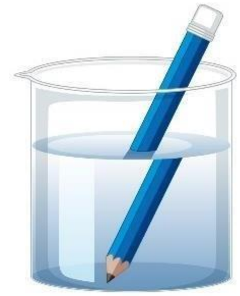


a) increase by 5° b) increase by 10°

c) decrease by 5° d) decrease by 10°

Third: Light refraction:





Occurrence:

When a beam of a parallel light rays falls on the interface (boundary surface) between two transparent media of different optical densities.

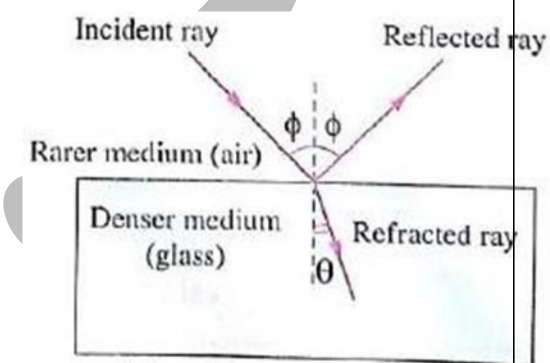
1) Part of the light gets reflected in the first medium.

2)Part of light passes to the second medium deviated from its direction and this phenomenon is known as **light refraction.**

3) Very small part of light gets absorbed in the second medium.

Optical density of a medium:

The ability of the medium to bend light rays when they enter into it.



Light refraction

It is a phenomenon that changes light's direction when it travels slanted through the interface between two transparent media of different optical densities.

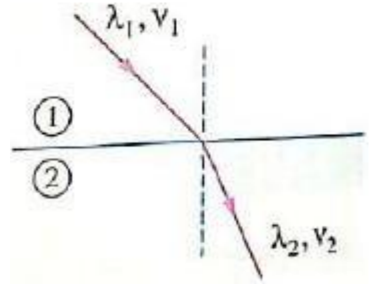
The angle of refraction (θ).

It is the angle between the refracted light ray and the normal line on the interface between the two media at the point of incidence.

The reason why the rays refracted between two mediums:

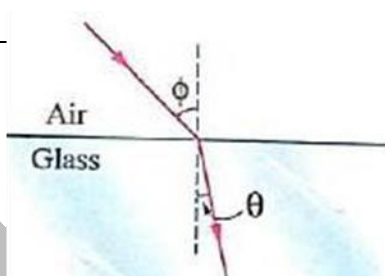
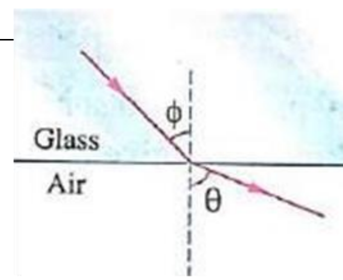
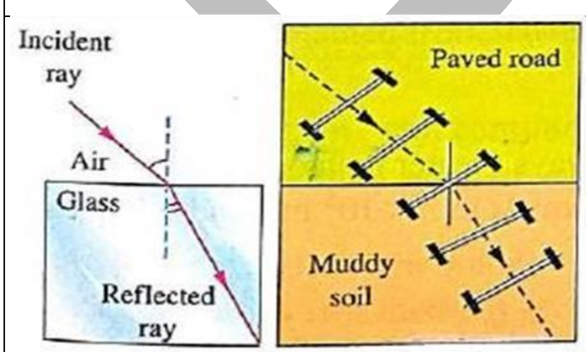
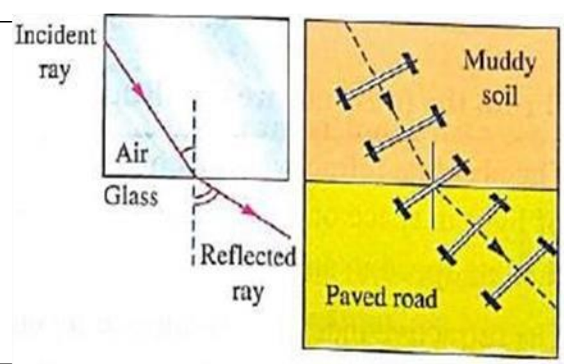
The refraction of light occurs due to the different speeds of light in the two media as a result of the different optical densities of the two media.

Light refraction obeys two laws, which are:



First law of refraction:

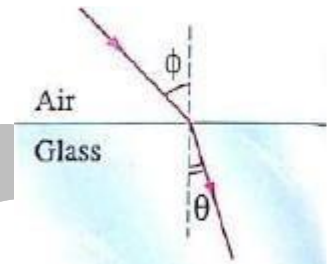
Second law of refraction:

An optically rarer medium To An optically denser medium	An optically denser medium To An optically rarer medium
From air to glass	From glass to air
So light rays are refracted (bent)	
	
This can be resembled by	
	

The factors affecting the relative refractive index between 2 media:

1. The types of the two media (their optical densities).
2. The wavelength of the incident light ray.

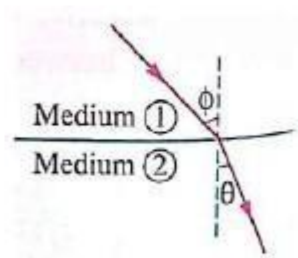
The absolute refractive index of a medium:



Snell's law:

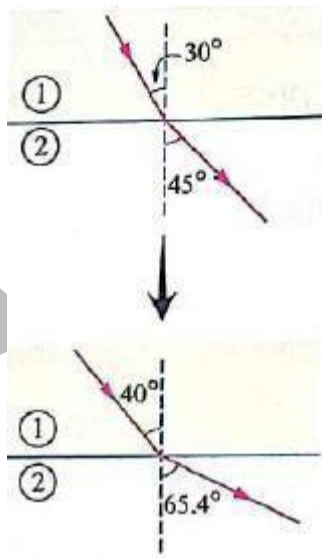
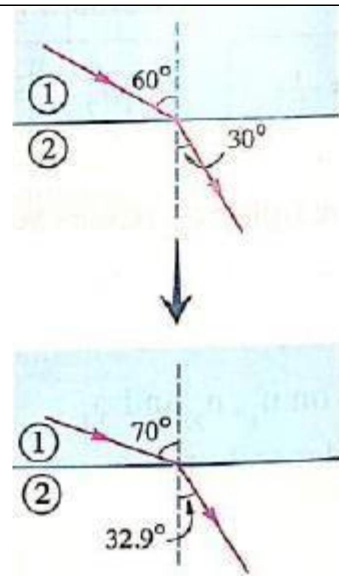
From the first law of refraction:

$$_1n_2 = \frac{Sin\phi}{Sin\theta} \quad , \quad _1n_2 = \frac{n2}{n}$$



$$\therefore \frac{Sin\phi}{Sin\theta} = \frac{n2}{n} \quad \text{so} \quad \boxed{n1 \sin \phi = n2 \sin \theta} \text{...(vip)}$$

First medium   second medium

If	
n1 > n2	n1 < n2
Then	
Ø < θ	Ø > θ
So, when increasing the angles of incidence (Ø) with a given value, the angles of refraction (θ) increase with	
A greater value Where $\frac{n1}{n2} > 1$	A lower value Where $\frac{n1}{n2} < 1$
Examples	
	

Example 1:

If the absolute refractive index of water is $\frac{4}{3}$ and the absolute refractive index of glass is $\frac{3}{2}$,calculate:

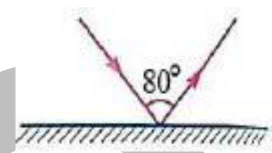
(a) The relative refractive index from water to glass.

(b) The relative refractive index from glass to water

Exercise (3)

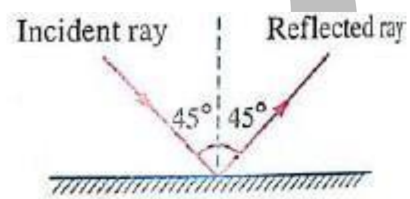
Choose the correct answer:

1) The opposite figure shows a light ray falling on the surface of a plane mirror and bouncing back, hence the angle of reflection of the ray from the surface of the mirror equals



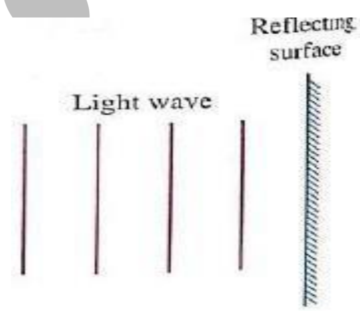
a) 40^o b) 50^o c) 80^o d) 100^o

2) In the opposite figure a light ray is incident with a speed (v) on the surface of a mirror and gets reflected from it, so the speed of the ray after its reflection becomes……………….



a) $\frac{1}{\sqrt{2}}$ v b) v c) $\sqrt{2}$ v d) 2 v

3)The opposite figure shows a light wave being incident on a reflecting surface, what will be the value of the angle of reflection for this wave after striking the reflecting surface?

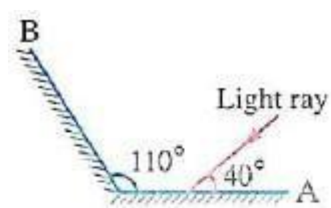


a) 0^o b) 45^o c) 90^o d) 180^o

4)If a light ray is incident perpendicular to a plane mirror, the angle of deviation of the ray from its path equals…………………

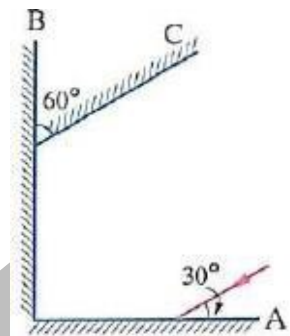
a) 0^o b) 90^o c) 360^o d) 180^o

5) In the opposite figure, the angle of reflection of the light ray from mirror B equals ....



a) 20^o b) 40^o c) 60^o d) 70^o

6) In the opposite figure, which of the following statements is correct?



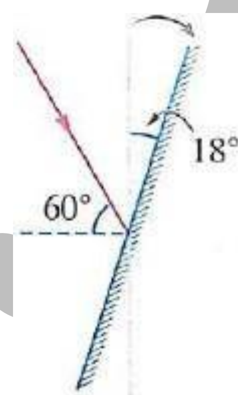
a) The ray is reflected from mirror C at an angle of 30°

b) The ray is reflected from mirror C at an angle of 45°

c) The ray is reflected from mirror C at an angle of 60°

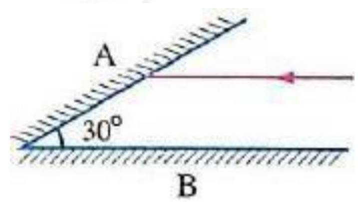
d) The ray is reflected parallel to mirror C.

7) A light ray is incident on a plane mirror with an angle of 60°. If the mirror is rotated by an angle of 18° in the clockwise direction while keeping the incident ray in the same direction as in the figure, then the angle of reflection becomes……………………



a) 18º b) 48º c) 42º d) 78º

8) If a light ray is incident on mirror A while being parallel to mirror B as shown in the opposite figure:



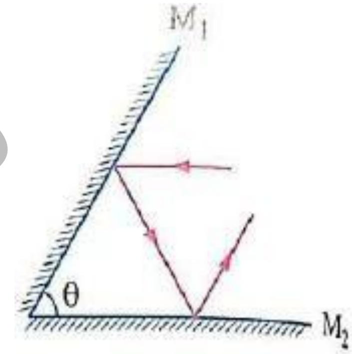
(i) The light ray gets reflected from mirror A and falls on mirror B by an angle of incidence that equals…………………

a) 90º b) 60º c) 30º d) 0º

(ii) The reflected light ray from mirror B falls again on mirror A with an angle of incidence that equals

a) 90° (b) 45° c) 30° d) 0°

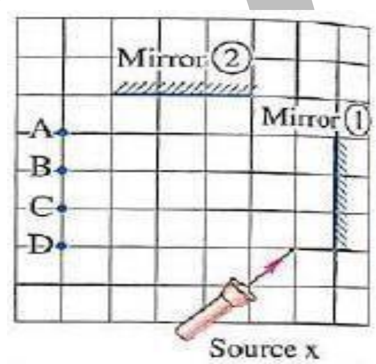
9) The opposite figure, a light ray is incident on mirror M_1 parallel to mirror M_2, hence the ray gets reflected from mirror M_1 to fall on mirror M_2 and get reflected from it parallel to mirror M_1 so angle θ equals...........



a) 30° b)45°

c) 60° d) 90°

10) The incidence of a laser ray from source x on mirror (1), hence after the ray gets reflected from mirror (2), it passes through point…………



a) A b) B
c) C d) D

11) When a light ray is incident from air with an acute angle on a glass surface, its direction gets change due to the change of........... between the two media.

a) The amplitude of light wave b) The color of light
c) The frequency of light d) The speed of light

12) When a light wave passes from an optically rare medium to another optically denser medium with an angle of incidence = zero, which of the following light properties does not change?

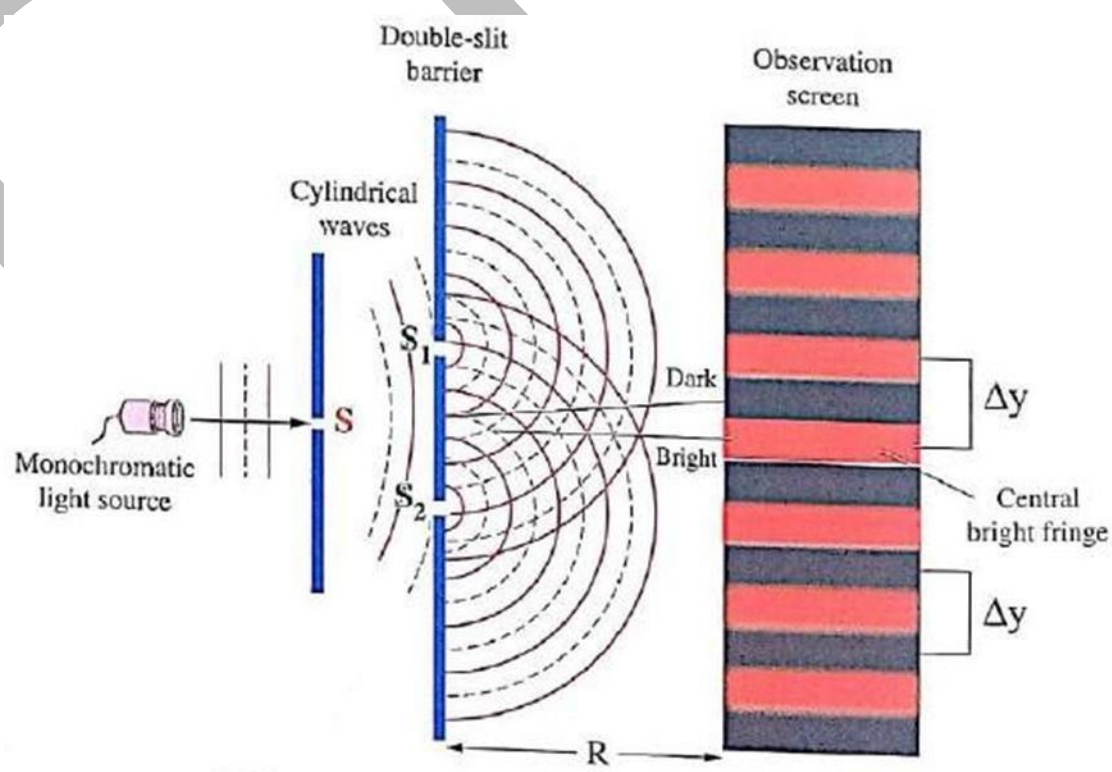
a) The wave speed b) The wave amplitude (intensity)
b) The direction of propagation d) The wavelength

Chapter 2: Properties of light

Lesson 2: (Interference and diffraction)

Third Interference of light:

1	2
A reinforcement in the intensity of the two waves at some positions "constructive interference"	A weakness in the intensity of the two waves at some other positions "destructive interference"
As a result of	
The overlap (superposition) of a crest from one wave with a crest from the other wave or a trough from one wave with a trough from the other wave.	The overlap (superposition) of a crest from one wave with a trough from the other wave.



Schematic diagram of Young's double-slit experiment

1- When turning on the light source, the light waves pass from slit S in the form of cylindrical waves, where:

- The continuous curves represent wave crests,
- The dashed curves represent wave troughs.

2The two slits (S,,S,) are adjusted, so when the light waves reach them, they will be at the same cylindrical wavefront, so they act as two coherent sources, i.e. They produce two coherent waves having the same frequency, amplitude and phase.

3The two waves from S_1 and S_2 propagate beyond the double slit barrier and when they reach the last screen, they interfere with each other and give a pattern of interference (as shown in the previous figure) and this phenomenon is known as the interference of light and it can be defined as follows:

<u>Interference of light:</u>

It is the phenomenon of superposition of the light waves that are produced from two coherent sources causing reinforcement in light intensity in some positions (bright fringes) and weakness in light intensity in other positions (dark fringes).

relation. $\Delta y = \boxed{\frac{\lambda R}{d}}$ ....vip

Where: (λ) is the wavelength of the used light, (R) is the distance between the double-slit barrier and the observation screen and (d) is the distance between the two slits.

As studying Young's double-slit experiment, we find that:

(1) Conditions for the occurrence of light interference:

- The used light source must be monochromatic.
- Slit S must be at equal distances from the two slits S_1, S_2 for making the double-slit work as two coherent light sources.

2- The interference of waves is of two types:

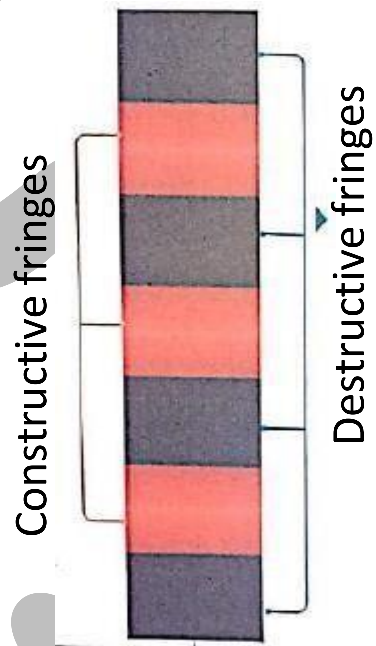
It produces :

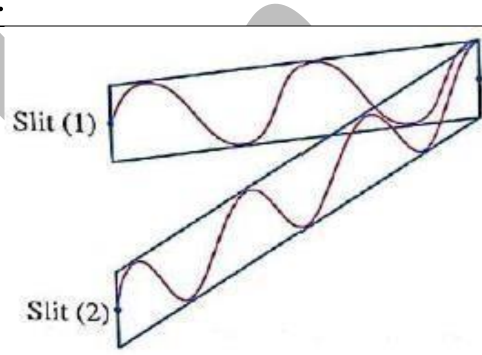
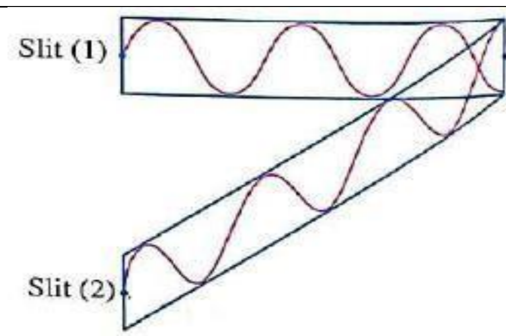
1 Constructive interference:

Reinforcement in the intensity of the light in some regions (bright fringes) as a result of the overlapping of a crest of one wave with a crest of another wave or a trough of one wave with a trough of another wave.

2 Destructive interference:

Weakness in the intensity of the light in some regions (dark fringes) as a result of the overlapping of a crest of one wave with a trough of another wave.

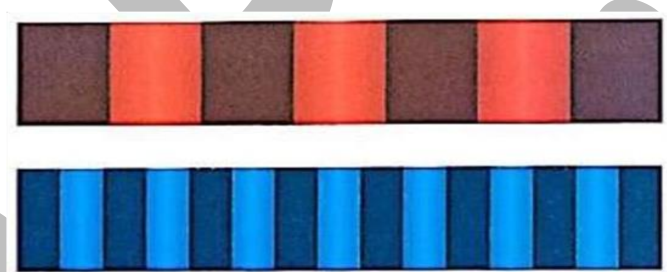


	Constructive fringes	**Destructive fringes**
condition	The path difference of the two interfered waves = $\mathbf{m}\lambda$	The path difference of the two interfered waves = $(\mathbf{m}+\frac{1}{2})\,\lambda$
Where: m is the order of the fringe which is an integer number (0,1,2, ...).		
Representatio		

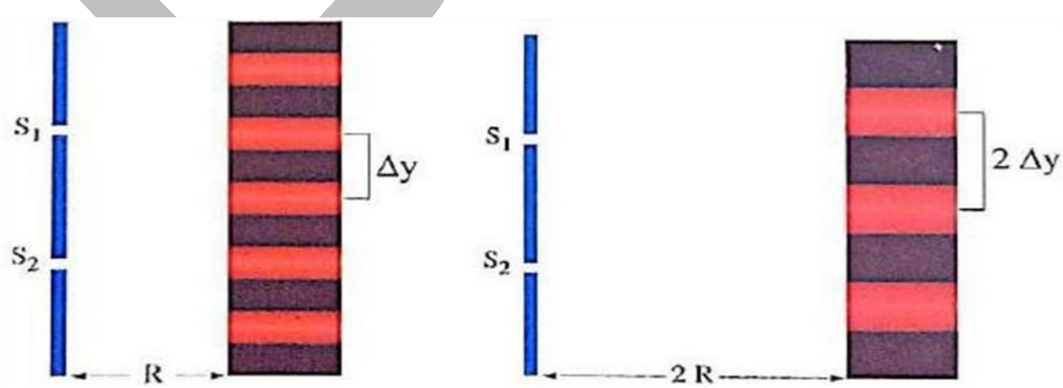
7- The two waves that have equal path lengths give the central fringe which is always a bright fringe because the path difference at this fringe equals zero, so the interference becomes constructive.

<u>The factors affecting the distance between the centers of two successive fringes of the same kind:</u>

2) In Young's double-slit experiment, it is preferable to use a light of relatively long wavelength to make the distance between the binterference fringes relatively large, hence the interference pattern becomes easier to be observed as shown in the following figure where $\lambda_b < \lambda_r$.



When increasing the distance between the double-slit barrier and the observation screen (R), the distance between the interference fringes increases according to the relation ($\Delta y = \frac{\lambda R}{d}$) as represented in the following figure:



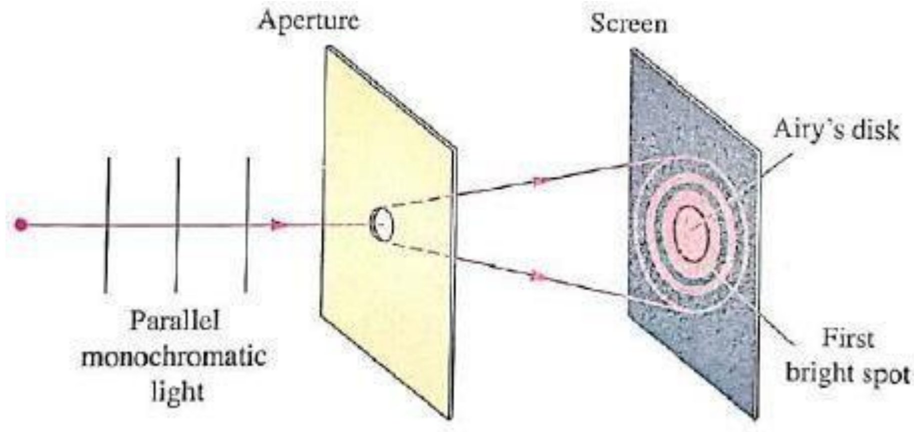
Example 1:

In double slit experiment; if the distance between the two narrow rectangular slits was 0.15 mm, the distance between the double –slit barrier and the observation screen was 75 cm and the distance between the centers of the two successive bright fringes was 0.3 cm, calculate the wavelength of the used monochromatic light source.

Example 2:

The opposite figure represents the interference pattern of Young's experiment which was conducted with a light of wavelength 5000 Å and an observation screen at distance 120 cm from the double-slit. If the distance between the central fringe (0) and the fourth bright fringe (4) was 0.8 cm, calculate the distance between the two slits.

Fifth Light diffraction:



Diffraction on a circular aperture

What happens can be explained as follows:

When monochromatic light waves fall on a sharp edge or on a circular aperture of a barrier whose size is small compared to the wavelength of the incident light:

•They change their direction of propagation (diffract).

•Each point on the wavefront of the wave passing through the aperture acts as a secondary light source that forms waves of the same wavelength and phase.

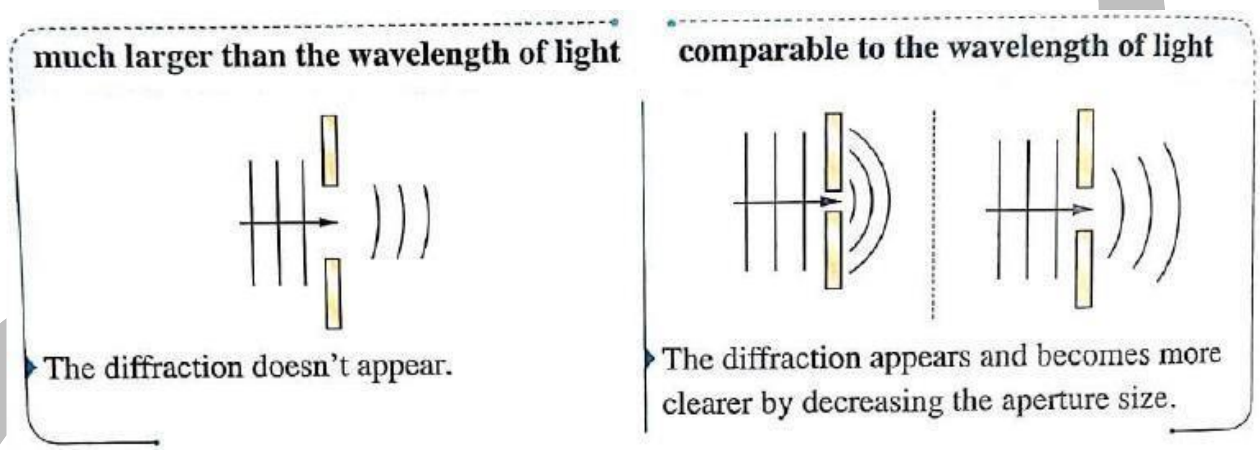
•These waves interfere (superpose with each other behind the aperture giving diffraction fringes.

Diffraction fringes pattern:

It is a pattern of alternate bright and dark regions produced due to the superposition of the diffracted light waves as passing from an aperture of a very small size or falling on a sharp edge.

The condition of a clear appearance of light diffraction:

The wavelength of the light wave has to be close in size to the dimensions of the aperture, so if the aperture size is:



From the previous, light diffraction can be defined as follows:

Diffraction of light:

It is the phenomenon of changing the direction of light waves propagation through the same medium when they pass through a very narrow aperture or fall on a sharp edge in which the superposition of waves leads to the formation of bright and dark fringes.

Interference	Diffraction
1 It appears when using a double-slit. 2Bright and dark fringes that are equally spaced are formed. 3Light intensities at the centers of the bright fringes are equal.	1 It appears when using a single narrow slit. 2Central wider bright fringe surrounded by less wide bright fringes are formed. 3light intensities at the centers of bright fringes get dimmer as we get away at the two sides from the central fringes

From the previous, the wave properties of light can be summarized as the following:

1. Light rays propagate in straight lines in the homogeneous medium.

2.They reflect when they fall on a reflecting surface, according to the laws of reflection.

3.They refract when they travel between two transparent media of different optical densities, according to the laws of refraction.

4.Light waves interfere when they meet other waves that have the same frequency, amplitude and phase producing regions of constructive interference (maxima) and regions of destructive interference (minima).

Exercise (4)

Choose the correct answer:

1) The interference of light, is resulted due to.........

a) the bouncing of waves b) the deviation of waves

c) the superposition of waves d) the change of the speed of light

2) The double-slit in Young's double slit experiment works as two coherent light sources, in which coherence means that the two waves formed from the double-slit have the same……………… .

a) phase b) amplitude c) speed d) direction

3)In Young's double-slit experiment, the widths of interference fringes don't depend on……………………

a) the distance between the two coherent sources

b)the distance between the double-slit barrier and the observation screen

c) the wavelength of the light emitted from the source

d) the distance between the double-slit barrier and the light source

4)In Young's double-slit experiment, the interference fringes widths increase when ....

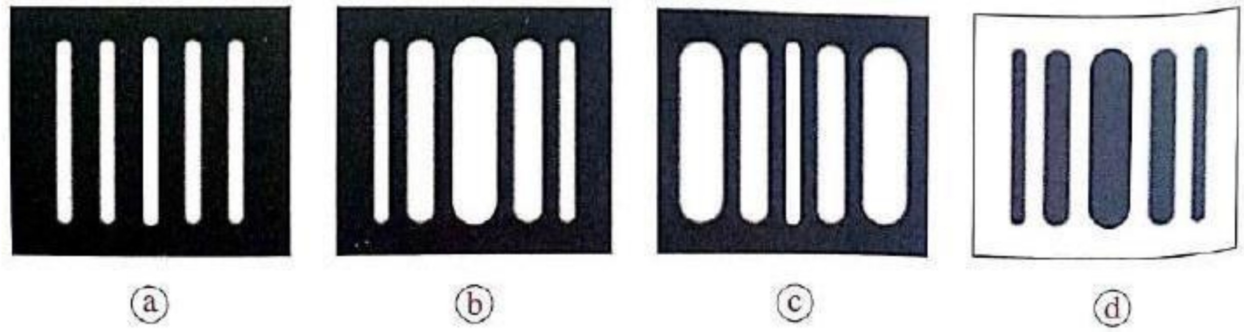
a)the distance between the double-slit and the observation screen decreases

b)the distance between the double-slit and the observation screen increases

c) the distance between the two slits increases

d) the wavelength of the used monochromatic light decreases

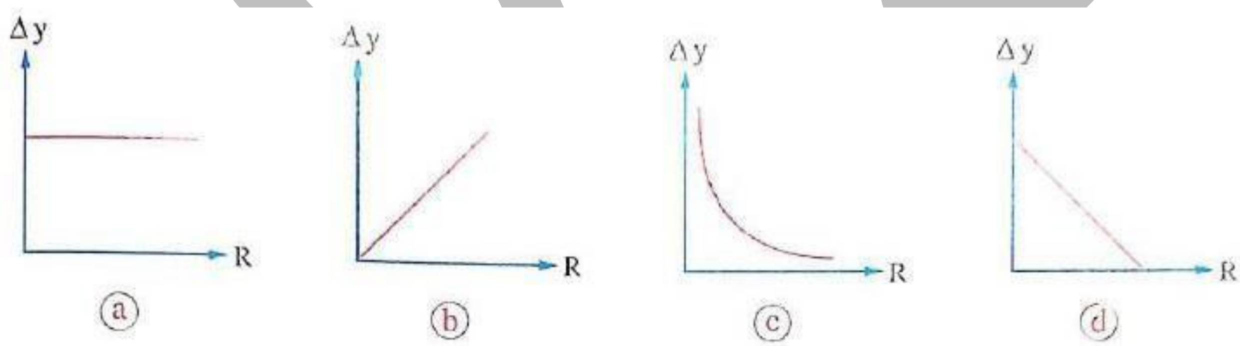
5) Which of the following figures represents the interference pattern formed in a Young's double slit experiment?



6)In a Young's double-slit experiment, when increasing the intensity of the used light, the distance between the center of the central fringe and that of the first dark fringe..............

a) increases b) decreases c) vanishes d) doesn't change

7) In Young 's double-slit experiment, which of the following figures, represents the graph of the distance between the center of the central fringe and the center of its following bright fringe (Δy) versus the distance between the double-slit barrier and the screen (R)?



8)A Young's double-slit experiment, the separation distance between the two slits was 10^{-4} m and the distance between two consecutive fringes of the same type was found to be 3.75 mm when they appeared on an observation screen at a distance 0.75 m from the two slits, so the wavelength of the used light equals....................

a) 5000 Å b) 5400 Å c) 6000 Å d) 6400 Å

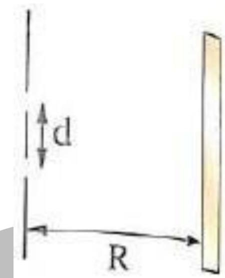
9)In a Young's double-slit experiment, if the distance between the two coherent sour was 1.6 mm where the interference fringes were formed on a screen at a distance of 60 cm from them such that the center of the third bright fringe was at 0.6 mm from the center ∅ the central fringe, then the frequency of the used light equals.............

(Given that: the speed of light in air = (3×10^8 m/s)

a) 4.08×10^{16} Hz b) 5.63×10^{14} Hz

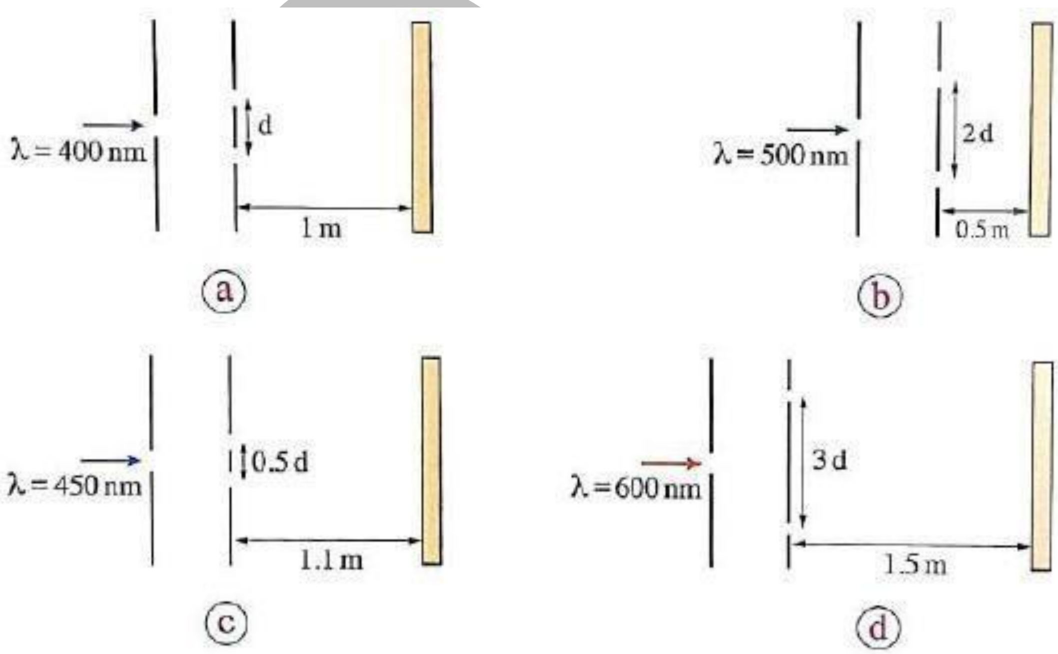
c) 4.74×10^{12} Hz d) 7.08×10^{11} Hz

10) In Young's double-slit experiment represented in the opposite figure, if $R = 10^4 d$, then............



a) $\Delta y = \lambda$
b) $\Delta y = 10^4 \lambda$
c) $\Delta y = 10^{-4} \lambda$
d) $\Delta y = \frac{\lambda}{10}$

11) Which of the following diagrams of Young's double-slit apparatus will yield the best noticeable interference fringes?

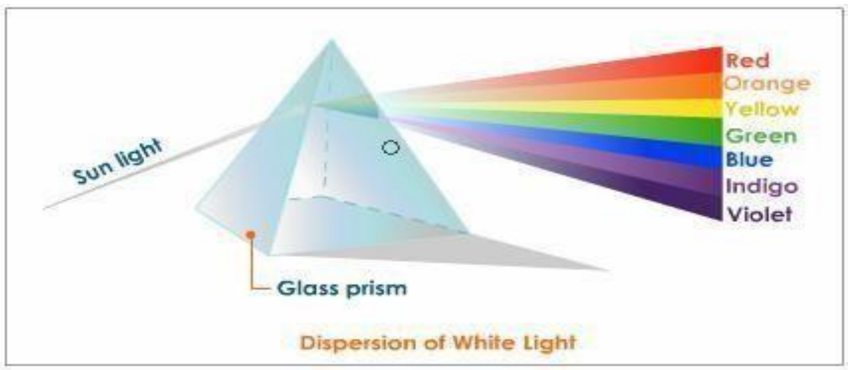


Chapter 2

Lesson 3: Total Internal Reflection

Light refraction can be used to explain the occurrence of two phenomena which are:

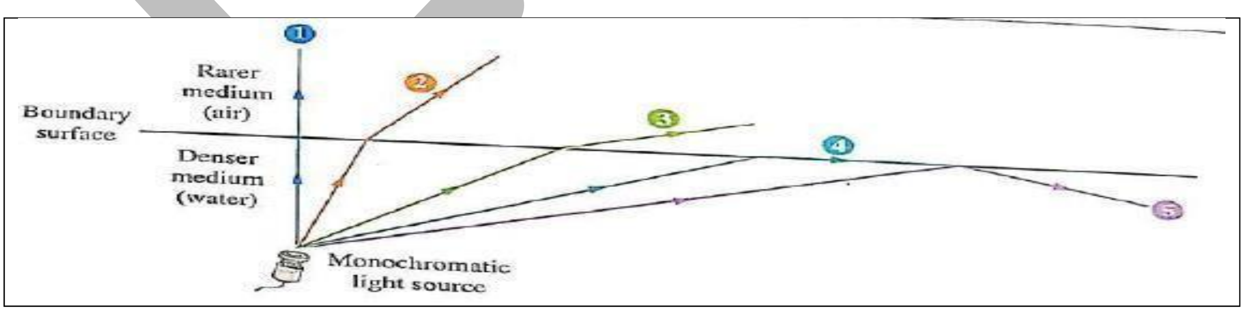
- The total internal reflection.
- The deviation of light in a triangular prism.



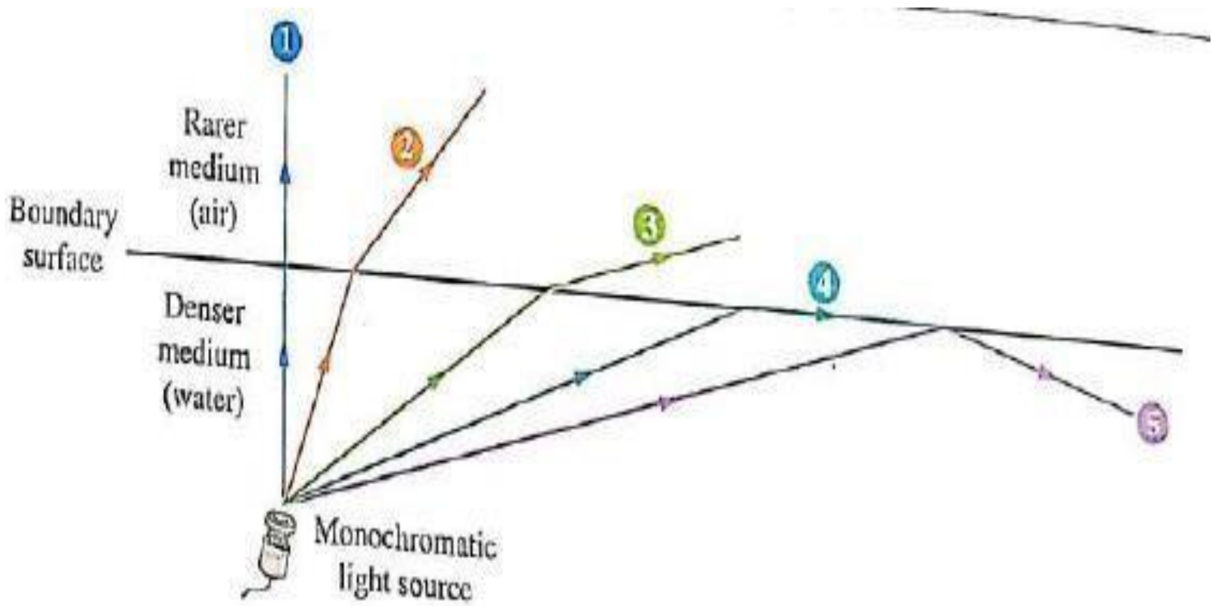
- In this lesson, we will study the total internal reflection of light in some details.

Total Internal Reflection:

Occurrence: When a ray of a monochromatic light falls from an optically denser medium (such as water) on the boundary surface with an optically less dense (rarer) medium (such as air), there will be some possibilities:



1- If the angle of incidence equals zero (the light ray falls perpendicular on the boundary surface (Ø = 0)	The light ray passes into the optically rarer medium (air) without any refraction (θ = 0)
2- If the angle of incidence is increased slightly to be greater than zero (the light ray falls at an angle on the boundary surface (Ø = 0)	The light ray passes into the optically rarer medium (air) refracted away from the normal on the boundary surface where n1 sin (Ø) = n2 sin (θ)
3- By increasing the angle of incidence of light gradually	The angle of refraction (θ) in the optically rarer medium (air) refracted away from the normal on boundary surface where n1 sin (Ø) = n2 sin (θ)
4- When the angle of incidence reaches a definite value that is known as the critical angle ($Ø_C$)	The light ray gets refracted tangent to the boundary surface i.e., the angle of refraction of the light ray (θ) equals 90°,so: n1 sin ($Ø_C$) = n2
5- When the angle of incidence becomes greater than the critical angle ($Ø_C$)	The light ray gets reflected back in the optically denser medium (water) so that the angle of incidence = the angle of reflection



From the previous, we can define each of the critical angle between two media and the total internal reflection as follows:

The critical angle between two media (ϕ_C)	The Total Internal Reflection
It is the angle of incidence of the light ray in the denser medium which leads to a refraction angle of 90° in the rarer medium.	It is the reflection of light ray in the denser medium when it is incident at an angle that is greater than the critical angle between the two media

Deducing the relation between the critical angle and the refractive index of a medium:

When a light ray passes from an optically denser medium (n_1) to an optically rarer medium (n_2), Snell's law is applied:

n1 sin (ϕ) = n2 sin (θ)

If the light ray falls with an angle of incidence that equals the critical angle (Ø_C) between the two media, it gets refracted tangent to the boundary surface:

$\text{Ø} = \text{Ø}_C$, θ=90 **so** n1 sin (Ø_C) = n2 sin (90)

$$\boxed{\therefore n1 \sin(\text{Ø}_C) = n2}$$

If the rarer medium is

Air ($n_2 = n_{air} = 1$)	Not air

So,

$n_1 = n$, $n \sin \phi_c = 1$	$n_1 \sin \phi_c = n_2$
$\sin \phi_c = \frac{1}{n} = \frac{v}{c} = \frac{\lambda_1}{\lambda_2}$	$\sin \phi_c = \frac{n_2}{n_1} = \frac{v_1}{v_2} = \frac{\lambda_1}{\lambda_2} = {}_1n_2 = \frac{\sin(\phi_c)_1}{\sin(\phi_c)_2}$

Where

Air:

- (n) is the absolute refractive index of the denser medium ($n > 1$).
- (ϕ_c) is the critical angle of the medium with air.

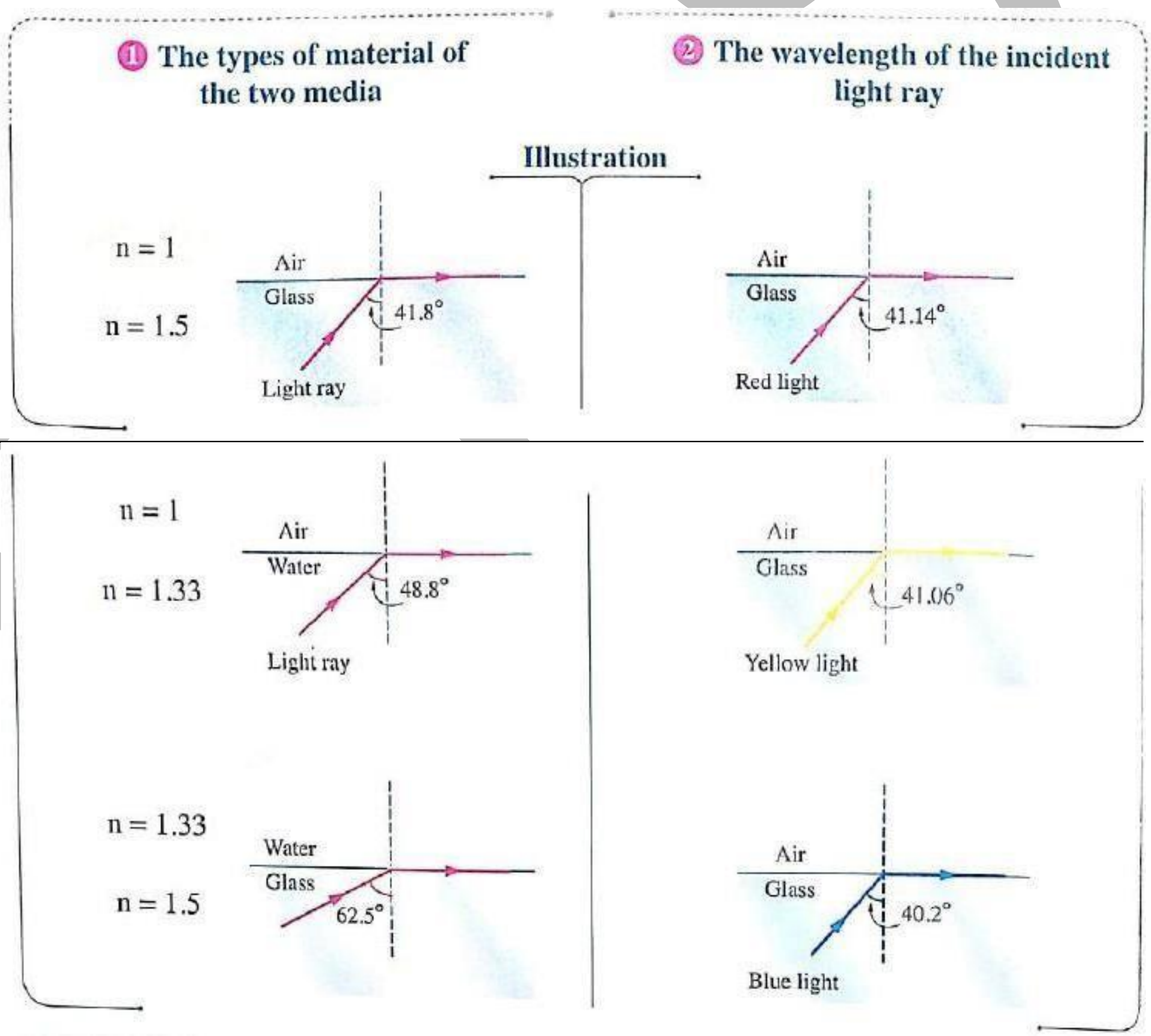
Not air:

- $n_1 > n_2$
- ϕ_c is the critical angle between the two media.
- $(\phi_c)_1$ is the critical angle of the first medium with air.
- $(\phi_c)_2$ is the critical angle of the second medium with air.

Note:

Knowing that sin (Ø_C) is always between 0 and 1 ($0 < \sin(\text{Ø}_C) < 1$), so when calculating the critical angle between two media, the value of the quantity in the numerator must be always less than the value of the quantity in the denominator.

The factors on which the critical angle between two media depends:



Example 1:

If the absolute refractive indices of glass and water for a given monochromatic light ray are 1.6 and 1.33 respectively, calculate:

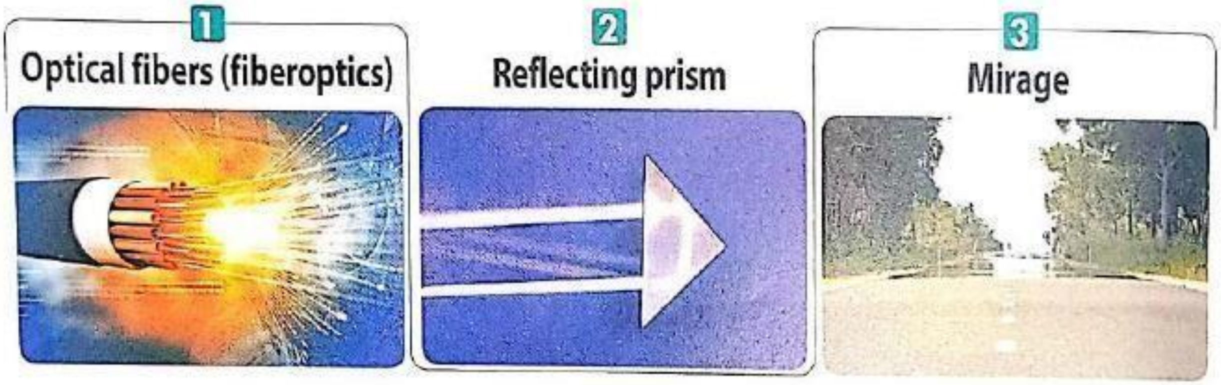
(a) The critical angle for each of them with air.

(b)The critical angle for the incident light ray that travels from glass to water.

Example 2:

The speeds of propagation of a light ware through two different media (x and y) are 2×10^8 m/s and 2.75×10^8 m/s respectively. Calculate the critical angle between the two media.

Application of the total internal reflection of light

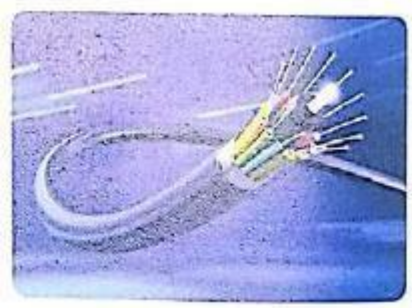


Optical fibers (fiber optics)

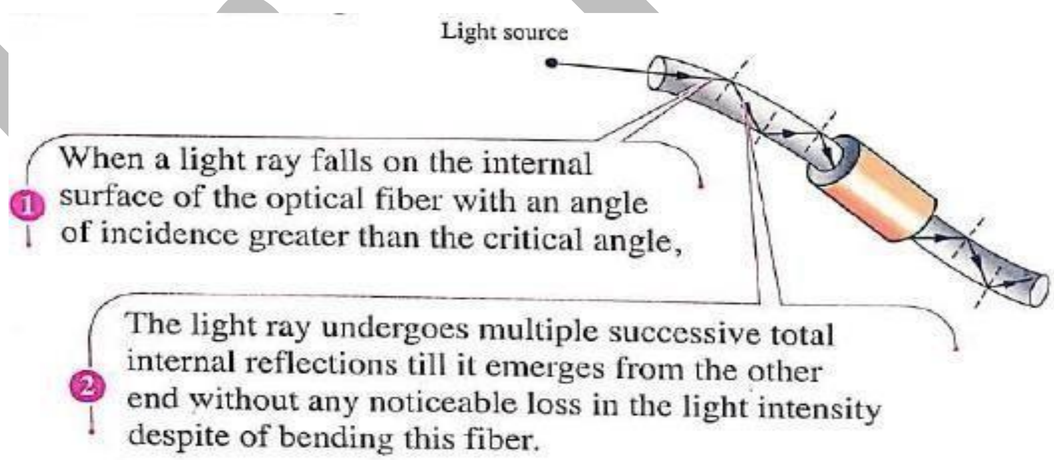
Structure:

It is a thread-like tube of a transparent elastic material, which has a relatively high refractive index.

Idea of work: total internal reflection



Explaining the idea of work:



Uses:

1Transferring light to parts which are hard to reach.

2Transmitting light in non-straight paths without much losses in the light intensity.

3 They are widely used nowadays in medical examination devices such as medical endoscopes, which are used in:

- Diagnosis.
- Operative surgery using laser beam.

4- Communication as light can carry signals of data in optical fiber cables

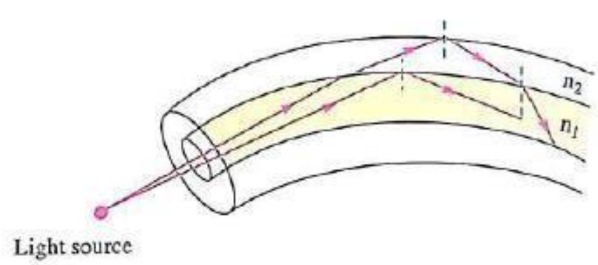
Notes:

Optical fiber that are made of two layers are preferred to the optical fibers that are made of only one layer;

Because the refractive index of the material of the external layer (n_2) is less than that of the internal layer (n_1).

Hence, the external layer reflects any part of light that may escape from the internal layer by total internal reflection so that light is kept travelling inside the fiber.

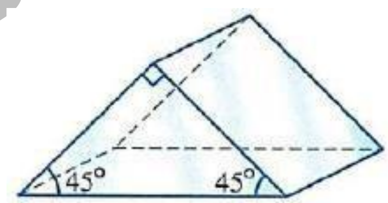
Accordingly, the intensity of the transmitted light by the optical fiber can be kept constant, which increases the efficiency of light transferring.



2-Reflecting prism:

Structure:

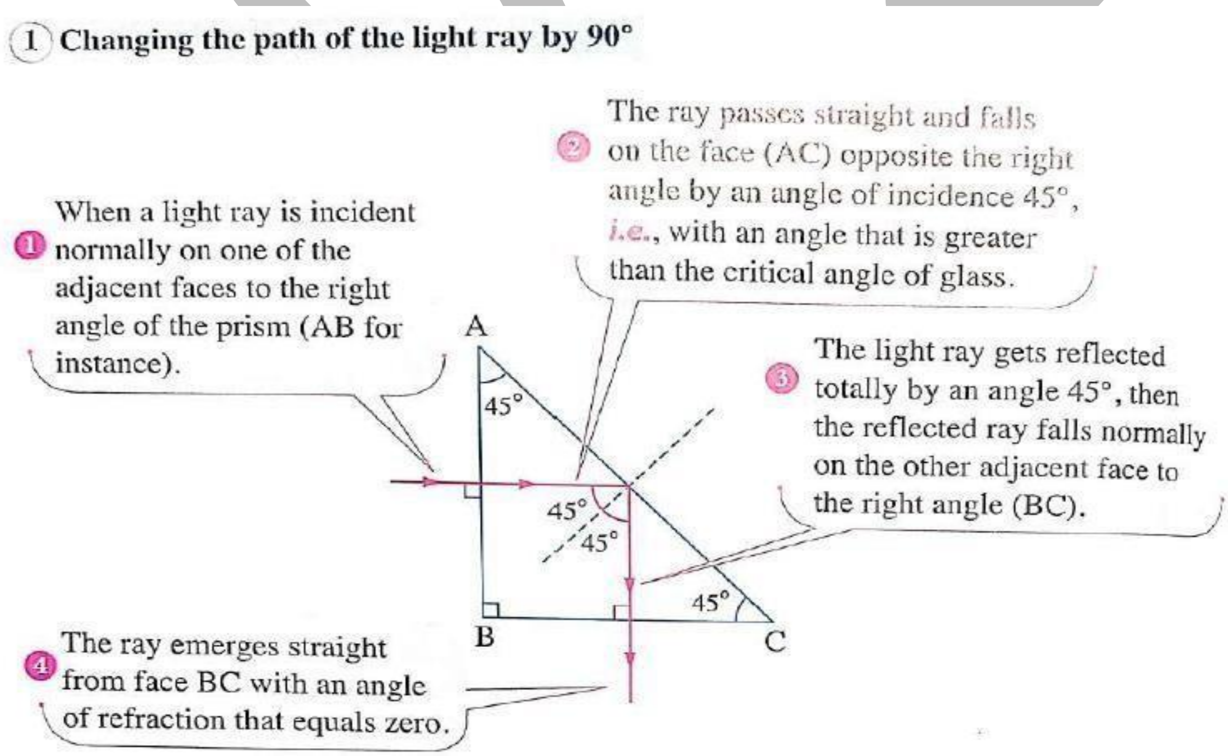
A triangular glass prism whose angles are 45°, 45° and 90° that is made of glass of refractive index 1.5
i.e. its critical angle with air is 41.8° (≈ 42°).



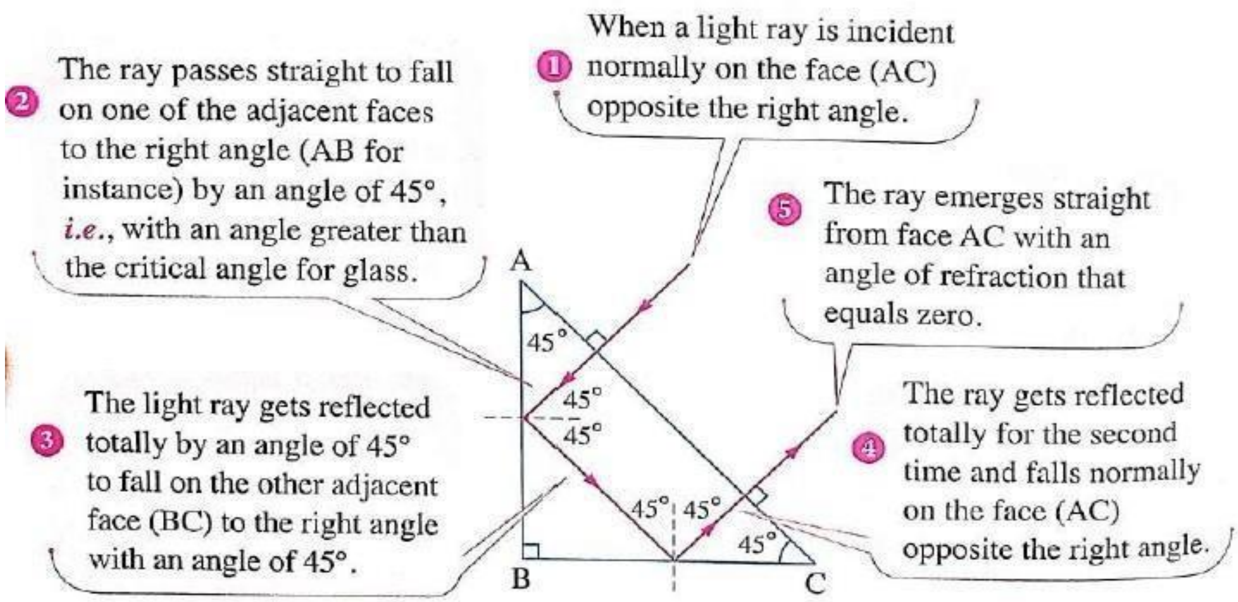
Idea of working: Total internal reflection.

Usage:

Changing the path of the light ray by 90°

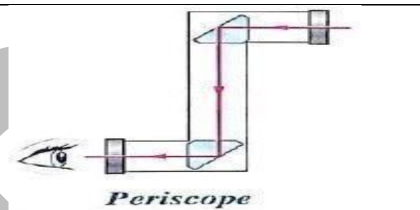
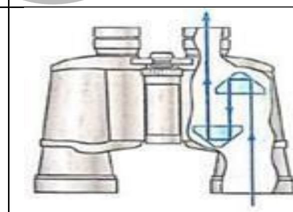


2 Changing the path of the light ray by 180°



<u>From previous, we can compare the two uses of reflecting prism as follows:</u>

	To change the path of the light ray by 90°	To change the path of the light ray by 180°
The prism's face on which the light ray fall	One of the right-angled Faces (face AB)	The face opposite the right angle (hypotenuse AC)
The angle of incidence (Ø)		
The deviation angle of light		
The angle of ray emergence		

The prism's face from which the light ray emerges		
The number of total internal reflections inside the prism		
An optical instrument that uses the prism		

Notes:

1. Reflecting prisms are preferred to metallic reflecting surfaces or mirrors in some optical instruments for the following reasons:

(1) Because they reflect light totally while there is no other reflecting surface of efficiency 100 %.

(2) In addition, a metallic surface eventually loses its luster, hence its reflection efficiency decreases, this does not happen in a prism.

2. The faces of a reflecting prism are coated with non-reflective layer of a material like cryolite (aluminum fluoride and magnesium fluoride) whose refractive index is less than that of glass.

3- Mirage:

Mirage is a common phenomenon at the noon times during the very hot days.

Exercise (5)

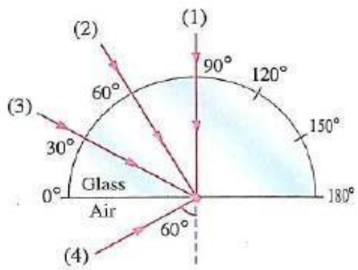
Choose the correct answer:

1) The total internal reflection for an incident light ray from an optically denser medium to an optically rarer medium occurs when the angle of incidence is •

a) equal to 90° (b) greater than the critical angle

c) equal to the critical angle d)less than the critical angle

2) The opposite figure represents four incident light rays on a semi-circular glass prism whose refractive index is 1.5, which of these rays undergoes total internal reflection?



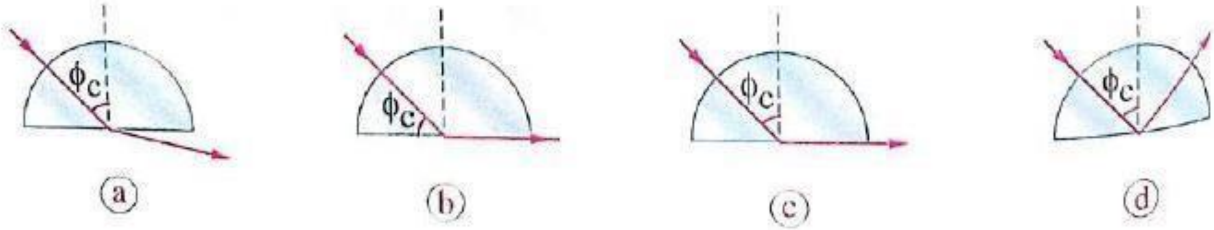
a) Ray (1) b) Ray (2) c) Ray (3) d) Ray (4)

3) The opposite table shows the absolute refractive indices of three materials x, y and z, hence total internal reflection could happen when light travels from

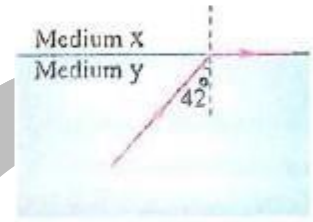
a) material x to material y
b) material x to material z
c) material y to material z
d) material z to material y

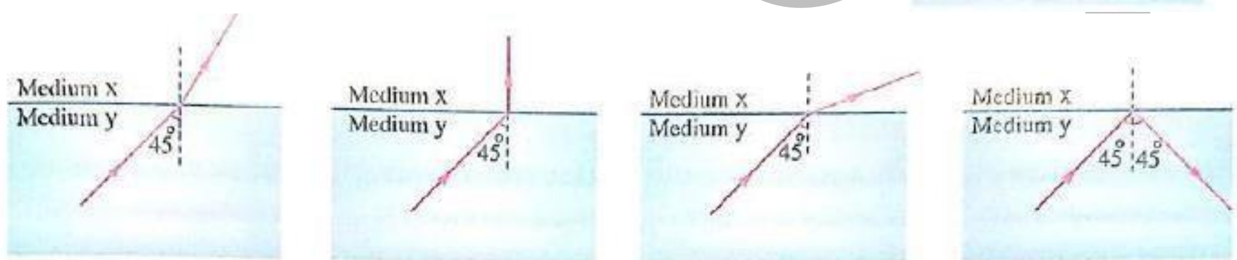
Material	Refractive index
X	1
Y	1.33
z	1.5

4) The figure that represents the correct path for an incident light ray on a semi-circular glass prism in which the angle ϕ_c, equals the critical angle is.............



5) In the opposite figure, if the angle of incidence becomes 45°, which of the following figures represents the correct path of the ray





6) The largest angle of refraction for a light beam passing from water of refractive index $\frac{4}{3}$ to air is……………

a) 41.82º b) 48.59º c) 90º d) 180º

7)A light ray falls from air on a liquid surface. If the angle of incidence is 30° and the angle of refraction is 22°, then the critical angle for the ray when it passes from the liquid to air is …………

a) 22° b) 30° c) 41.4° d) 48.5°

8) The critical angle between two media depends on ....

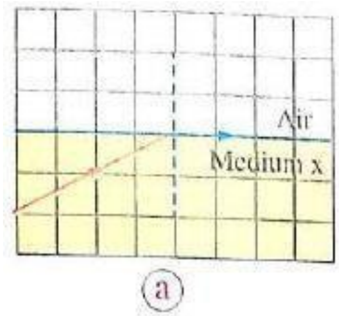
a) the absolute refractive index of the optically denser medium only

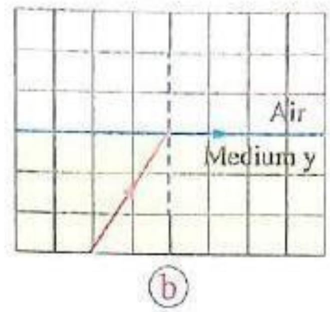
b) the absolute refractive index of the optically rarer medium only

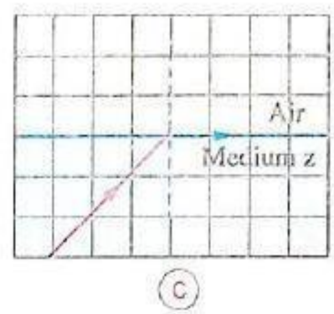
c) the absolute refractive indices of the two media

d)The angle of incidence of the light ray on the boundary surface between the two media

10) Three transparent materials have absolute refractive indices n_x, n_y, and n_z, a light ray is incident on the interface of each of them with air as represented in the following figures







So the speed of light…………………

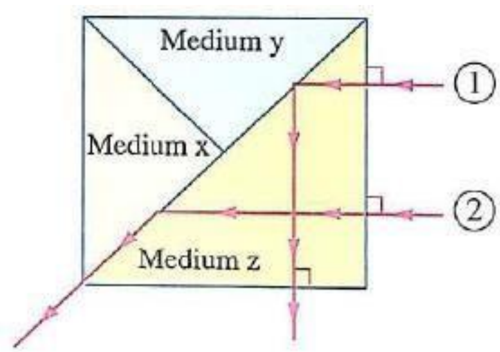
a) is higher in medium x

b) is higher in medium y

c) is higher in medium z

d) is the same in all of them

11) The opposite figure shows the paths of two light rays, so what is the correct order for the absolute refractive indices of the three media x, y and z?



a) $n_z < n_y < n_x$ b) $n_y < n_x < n_z$

c) $n_z < n_x < n_y$ d) $n_x < n_y < n_z$

12) Which light color has the least value of critical angle in glass surrounded by air ……………

1) Red b) Green c) Yellow d) Violet

Essay questions: (explain the following)

1- Despite the falling of a light ray from an optically denser medium to an optically rarer medium, it doesn't undergo total internal reflection

………

………

2When light is emitted from a source beneath the surface of water, it might not be seen in air.

………

………

3 Optical fibers are used in medical endoscopes.

………

………

4Prisms are preferred to mirrors as reflectors in some optical instruments.

………

………

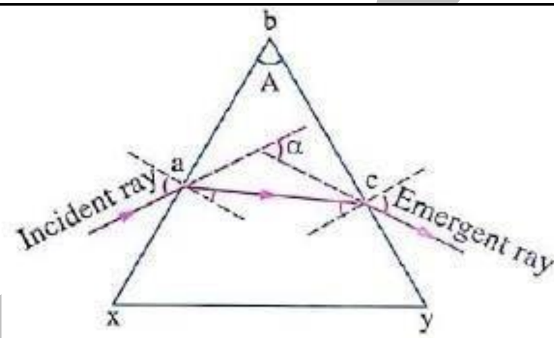
5 The appearing of mirage in hot deserts.

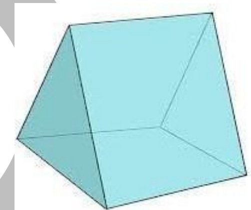
………

………

Chapter 2

Lesson 4: Deviation of light in triangular prism





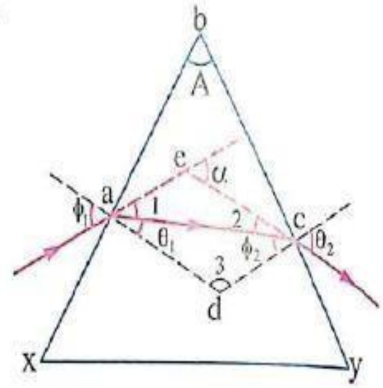
The angle of deviation (α):

It is the acute angle between the extensions of the incident light ray and the emergent light ray.

Deducing the laws of triangular prism:

In the triangular prism shown in the opposite figure:

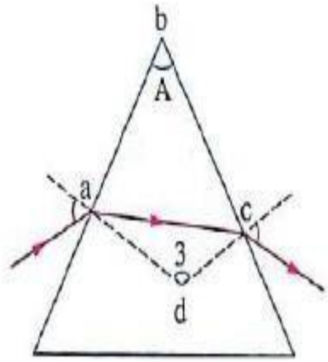
- A is the apex angle of the prism (the angle between the two faces of the prism where the light ray enters through one of them and emerges from the other one)
- ϕ_1 is the first angle of incidence (where light enters)
- θ_1 is the first angle of refraction
- ϕ_2 is the second angle of incidence (inside the prism)
- θ_2 is the angle of emergence
- α is the angle of deviation



Hence we can deduce each of:

<u>First The apex angle of prism (A):</u>

1



$\because \overline{ad} \perp \overline{ab}$, $\overline{dc} \perp \overline{cb}$

i.e. $\angle$ bad = 90° , $\angle$ bcd = 90°

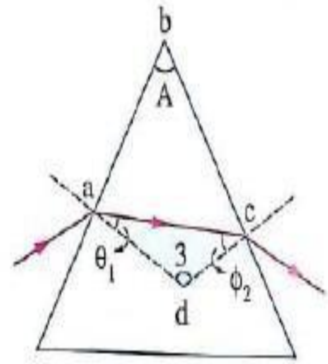
$\therefore \angle$ bad + $\angle$ bcd = 180°

$\therefore$ Shape abcd is cyclic quadrilateral.

$\therefore$ The sum of each two opposite angles = 180°

$\therefore A + \hat{3} = 180°$

2



In the triangle acd :

$\because$ The sum of angles = 180°

$\therefore \theta_1 + \phi_2 + \hat{3} = 180°$

From 1 and 2

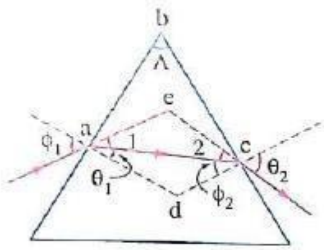
3.

$$\therefore A + \hat{3} = \theta_1 + \phi_2 + \hat{3}$$

$$\therefore \boxed{A = \theta_1 + \phi_2}$$

Second The angle of deviation (α):

1

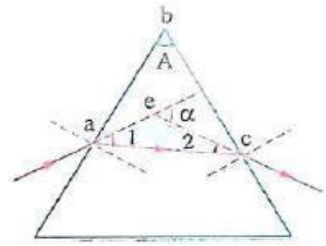


$\because \phi_1 = \hat{1} + \theta_1 \quad , \quad \theta_2 = \hat{2} + \phi_2$

(since they are vertical opposite angles)

$\therefore \hat{1} = \phi_1 - \theta_1 \quad , \quad \hat{2} = \theta_2 - \phi_2$

2



$\because$ The angle of deviation is an exterior angle of the triangle aec.

$\therefore \alpha = \hat{1} + \hat{2}$

From 1 and 2

3

$$\therefore \alpha = \phi_1 - \theta_1 + \theta_2 - \phi_2$$

$$= \phi_1 + \theta_2 - (\theta_1 + \phi_2)$$

$$\because A = \theta_1 + \phi_2$$

$$\therefore \boxed{\alpha = \phi_1 + \theta_2 - A}$$

Third The refractive index of the material of the prism (n):

When a light ray passes from a medium to a prism such that if the medium is:

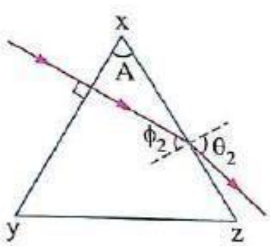
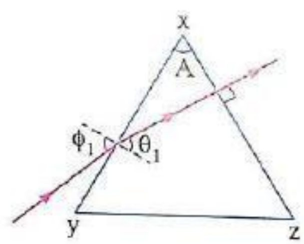
Air	Other medium, not air
$n_{prism} = \dfrac{\sin \phi_{1\,(air)}}{\sin \theta_{1\,(prism)}} = \dfrac{\sin \theta_{2\,(air)}}{\sin \phi_{2\,(prism)}}$	${}_{medium}n_{prism} = \dfrac{n_{prism}}{n_{medium}} = \dfrac{\sin \phi_{1\,(medium)}}{\sin \theta_{1\,(prism)}} = \dfrac{\sin \theta_{2\,(medium)}}{\sin \phi_{2\,(prism)}}$

Then

If the triangular prism is surrounded by air, then the factors that affect each of:

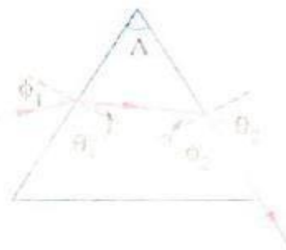
The angle of refraction (θ_1)	are:	1) The refractive index of the prism for the used light (n) 2) The first angle of incidence ($Ø_1$)
The second angle of ($Ø_2$) The angle of emergence (θ_2) The angle of deviation (α)	are:	1) The refractive index of the prism for the used light (n) 2) The first angle of incidence ($Ø_1$) 3) The apex angle (A)

Special cases for the triangular prism:

	① When the light ray falls normal on the face of the prism	② When the light ray emerges normal from the face of the prism
The ray	enters through face xy without any refraction	emerges from face xz without any refraction
		
Such that	$\phi_1 = \theta_1 = 0°$ (the minimum value for the first angle of incidence)	$\phi_2 = \theta_2 = 0°$ (the minimum value for the angle of emergence)
So that	$\phi_2 = A$ (the maximum value for the second angle of incidence)	$\theta_1 = A$ (the maximum value for the second angle of incidence)
At the emergence of the ray from face xz	$\alpha = \theta_2 - A$	$\alpha = \phi_1 - A$

3 When the second angle of incidence (ϕ_2) equals the critical angle of the prism:

In this case ϕ_1 is the minimum angle of incidence on the face of the prism that makes the ray emerge tangent to the opposite face



$\because \phi_2 = \phi_c \ , \ \theta_2 = 90°$

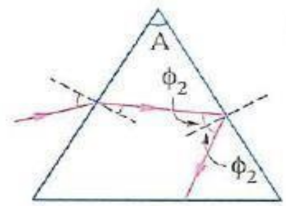
$\therefore n = \frac{1}{\sin \phi_2} \ , \ A = \theta_1 + \phi_c$

4 When the second angle of incidence (inside the prism) is greater than the critical angle of the prism:

The ray encounters total internal reflection where:

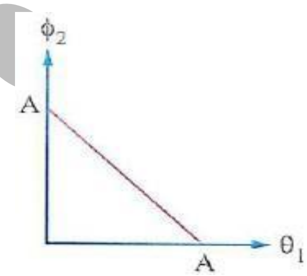
The angle of reflection = The second angle of incidence

And the ray falls on the third face of the prism.



<u>Notes:</u>

(1) The graph of the second angle of incidence ($Ø_2$) versus the angle of refraction (θ_1) can be represented as shown in the opposite figure, where: $Ø_2 = A - \theta_1$



(2)When a light ray is incident with an angle ($Ø_1$) on one of the faces of a triangular prism such that the second angle of incidence ($Ø_2$) is less than the critical angle ($Ø_c$), the ray emerges from the opposite face with an angle of emergence (θ_2) and when increasing the first angle of incidence ($Ø_1$):

The first angle of refraction (θ_1) increases since $n = \frac{\sin Ø1}{Sin\ \theta 1}$

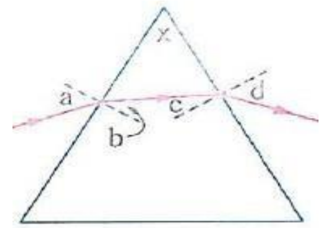
The second angle of incidence ($Ø_2$) decreases since $A = Ø_2 + \theta_1$

The angle of emergency (θ_2) decreases since $n = \frac{\sin \theta 2}{\sin Ø2}$

Exercise (6)

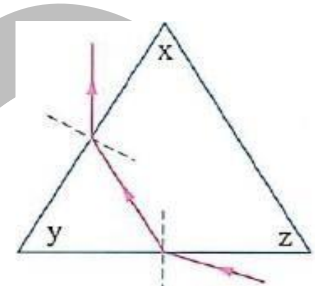
Choose the correct answer:

1) The opposite figure represents the path of a light ray through a triangular prism, what is the mathematical expression that relates correctly angle x with the other shown angles in the figure?



a) x= a + d b) x= a – b c) x= b- c d) x= b + c

2) In the opposite figure, which angle represents the apex angle of the prism when calculating the deviation angle of the light ray?



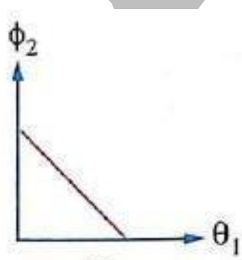
a) Angle x b) Angle y

c) Angle z d) Any of them

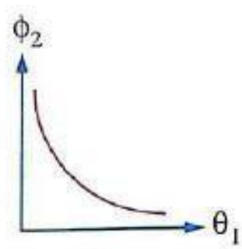
3) A ray of light falls on a triangular glass prism at an angle of incidence of 45° and emerges with an angle of 52°. If the refractive index of the prism material is 1.5, then its apex angle equals ……………

a) 28.13° b) 30.18° c) 31.69° d) 59.82°

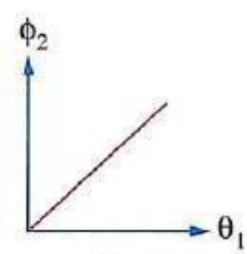
4) Which of the following graphs represents the relation of the second angle of incidence (ϕ_2) versus the angle of refraction (θ_1) for a light ray that gets incident on the face of a triangular prism with different angles of incidence?



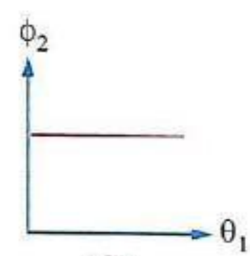
(a)



(b)

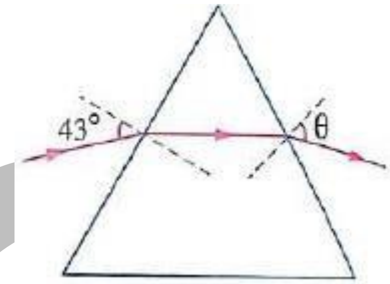


(c)



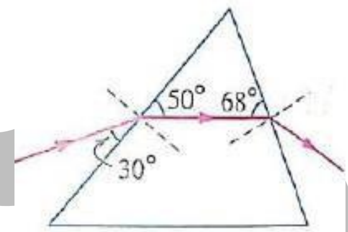
(d)

5) The opposite figure shows the path of a light ray through an equilateral triangular prism of refractive index 1.5, so the value of angle θ equals…………



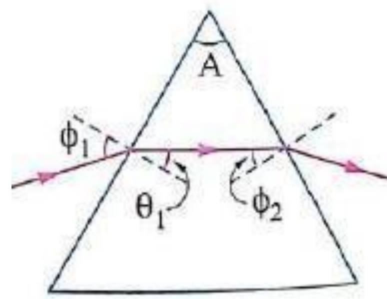
a) 47.2º b) 43º c) 54.8º d) 27º

6) The opposite figure shows the path of a light ray through a triangular prism, then the angle of deviation for the ray equals……………



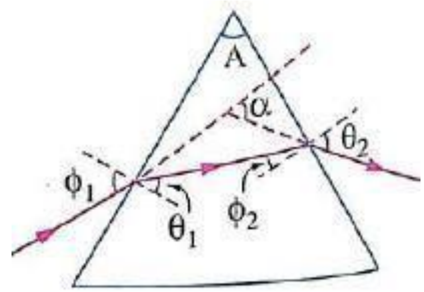
a) 22º b) 28.38º c) 30º d) 30.38º

7) In the opposite figure, what is the effect of increasing the angle of incidence (ϕ_1) on the angle of refraction (θ_1) and the second angle of incidence (ϕ_2)?



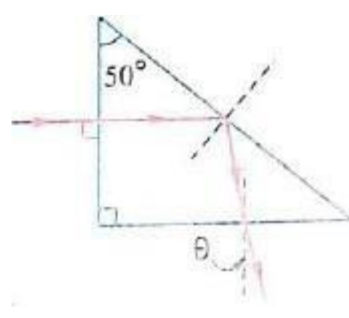
a) Both angles increase.
b) Both angles decrease.
c) (θ_1) increases and (ϕ_2) decreases
d) (θ_1) decreases and (ϕ_2) increases.

8) In the opposite figure if (ϕ_1) > (θ_1) and α = **A** so the angle of incidence (ϕ_1) could be equal to …………



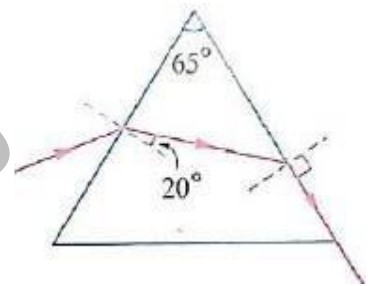
a) $\frac{1}{2}$ **A** b) **A** c) $\frac{1}{2}$ **A** d) **2 A**

9) In the opposite figure, if the refractive index of the prism's material is 1.5, then the value of angle (θ) almost equals.............



a) 20º b) 18º c) 15º d) 10º

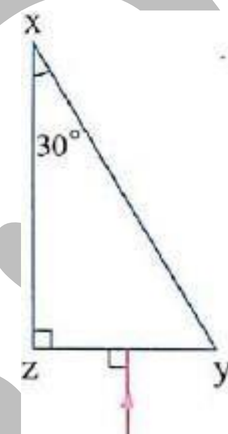
10) The opposite figure represents the path of a light ray through a triangular prism, hence the deviation angle of the light ray equals………



a) 65° b) 53.9°

c) 45° d) 28.9°

11) In the opposite figure, a ray falls perpendicularly on face yz of a triangular prism. If the critical angle of the prism's material is 42°, which statement of the following is correct?



(a) The ray passes through face yz without deviation.

b) The angle of incidence of the ray on face xy equals 60°

c) The ray gets reflected totally on face xy.

d) All the previous.

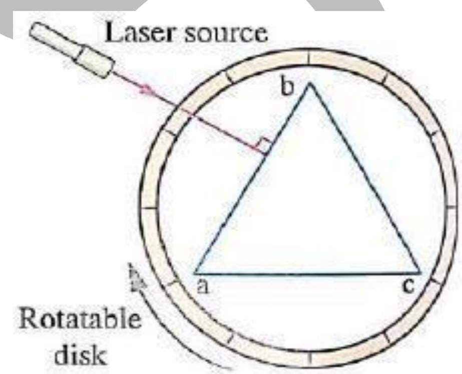
12) The apex angle of a triangular prism is 30°, a light ray falls perpendicularly on one of its faces, so it gets deviated by an angle that equals 20°, so the refractive index of the prism material is ………………

a) 1.25 b) 1.44 c) 1.53 d) 1.66

Chapter 2

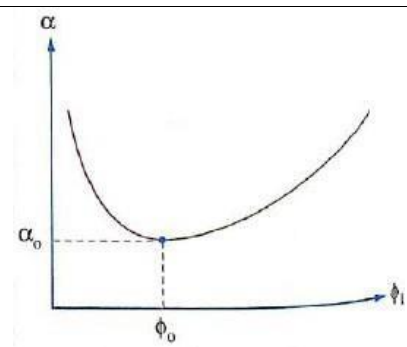
Lesson 5: Minimum Deviation in a Triangular Prism and Thin Prism

The opposite figure represents the incidence of a light ray perpendicularly on face ab of a triangular prism abc that is placed on a rotatable disk, so if the disk has been rotated to increase the angle of incidence of the light ray ($Ø_1$), then measuring the angle of emergence from face bc multiple times and after that calculating the angle of deviation (a) each time from the relation:



$$a = Ø_1 + \theta_2 - A$$

Then, when plotting a graph of deviation angle (a) versus the first angle of incidence ($Ø_1$) for the light ray, we find that:

At a small angle of incidence ($Ø_1$), the angle of deviation (a) will be large and as the first angle of incidence ($Ø_1$) increases, the angle of deviation (a) decreases.	
At a certain angle of incidence (˜$_0$), the angle of deviation reaches its minimum value (a_0), hence in this case the prism becomes in the minimum deviation position.	
By increasing the first angle of incidence ($Ø_1$) above its value at the minimum deviation position, the angle of deviation (a) increases again.	

It was found that at minimum deviation position:

The angle of emergence (**θ_2**) = The angle of incidence (**ϕ_1**) = **ϕ_0**

The second angle of incidence (**ϕ_2**) = The angle of refraction (**θ_1**) = **θ_0**

Calculating the refractive index of the prism's material at the minimum deviation position:

$$\phi_1 = \theta_2 = \phi_o$$

$$\because \alpha = \phi_1 + \theta_2 - A$$

$$\therefore \alpha_o = 2\,\phi_o - A$$

$$\therefore \phi_o = \frac{\alpha_o + A}{2}$$

$$\theta_1 = \phi_2 = \theta_o$$

$$\because A = \theta_1 + \phi_2$$

$$\therefore A = 2\,\theta_o$$

$$\therefore \theta_o = \frac{A}{2}$$

Applying Snell's law:

$$\boxed{n_{medium} \sin \phi_o = n_{prism} \sin \theta_o}$$

So, if the medium surrounding the prism is:

Air

$$\therefore n_{prism} = \frac{\sin \phi_o}{\sin \theta_o}$$

$$\therefore n_{prism} = \frac{\sin\left(\frac{\alpha_o + A}{2}\right)}{\sin\left(\frac{A}{2}\right)}$$

Another medium other than air

$$\therefore \frac{n_{prism}}{n_{medium}} = \frac{\sin \phi_o}{\sin \theta_o}$$

$$\therefore \frac{n_{prism}}{n_{medium}} = \frac{\sin\left(\frac{\alpha_o + A}{2}\right)}{\sin\left(\frac{A}{2}\right)}$$

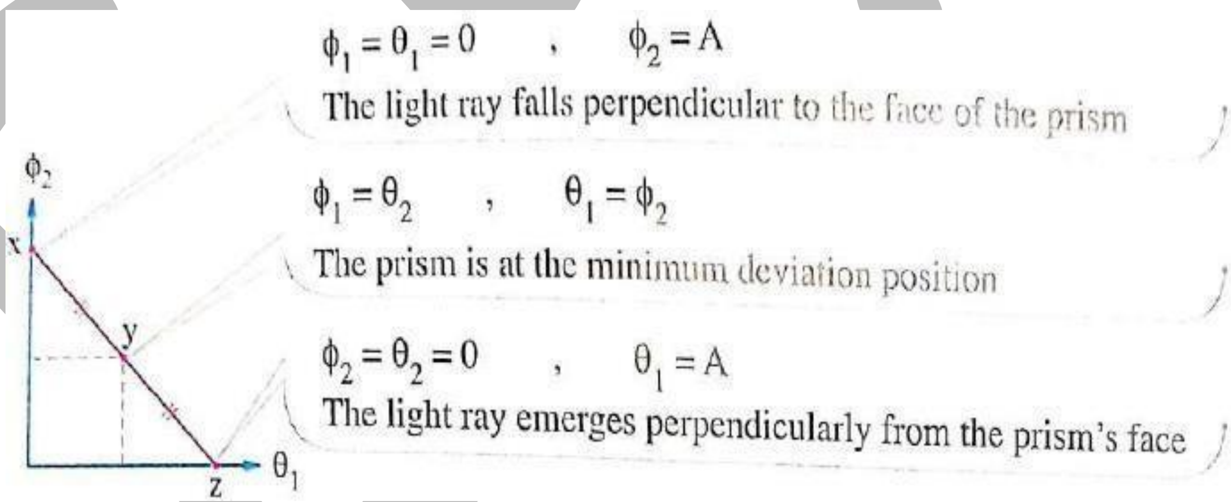
The relation between: The second angle of incidence (ϕ_2) and the angle of refraction (θ_1) in triangular prism:

The first angle of refraction (**θ_1**) and the second angle of incidence (**ϕ_2**) are related by the relation:

$A = \theta_1$

$\therefore \phi_2 = A - \theta_1$

Since the apex angle (A) is constant for the same prism, so as **θ_1 increases, ϕ_2 decreases** and the relation between them **(θ_1, ϕ_2)** can be represented as follows:



The factors on which the angle of minimum deviation () depends in a triangular prism:

1 The apex angle of the prism (A) :

As The apex angle of the prism (A) Increases, The minimum angle of deviation (α_0) Increases

2 The refractive index of the prism's material for the used light (n) :

As The refractive index of the prism's material for the used light (n) Increases, The minimum angle of deviation (α_0) Increases

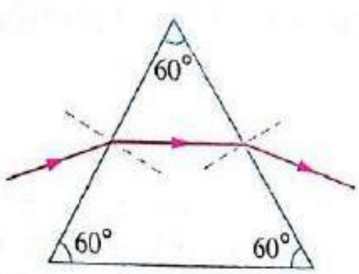
3 The wavelength of the used light (λ) :

As The wavelength of the used light (λ) Decreases, The minimum angle of deviation (α_0) Increases

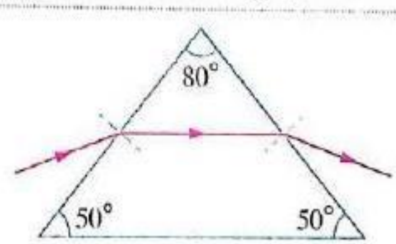
Note:

- In the minimum deviation position, the light ray inside the triangular prism will be parallel to the base if the prism is:

① Equilateral



② Isosceles (for the two sides through which the ray enters and emerges)



Example 1:

A triangular prism is made of a material whose refractive index is $\sqrt{2}$ having an apex angle that equals 60°, calculate:

(a) The minimum angle of deviation in the prism.

(b)The angle of incidence and the angle of emergence at minimum deviation.

Example 2:

A triangular prism has an apex angle of 60°. If the first angle of incidence equals double the angle of refraction at the minimum deviation of a red light ray through that prism, calculate the minimum angle of deviation.

Example 3:

The opposite graph represents the relation between the angle of deviation (α) for a light ray passing through a triangular prism and the

first angle of incidence (ϕ_1) on the face of the prism, calculate:

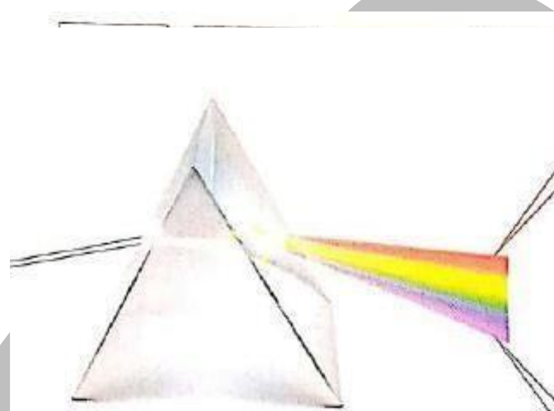
(a) The apex angle of the prism.
(b) The refractive index of the prism.
(c)The angle of emergence from the
prism at point x.

Dispersion of light by the triangular prism:

Visible (white) light consists of a range of wavelengths that extends nearly from 400 nm to 700 nm, hence if a beam of white light falls on a triangular prism in the minimum deviation position, it emerges from the prism separated into a spectrum of colors that can be assigned to seven colors of spectrum which can be listed as their order from the apex to the base of the prism as follows:

Explaining the dispersion of light by a triangular prism:

As the wavelength (A) of light increases, the index of refraction (n) which this light encounters at entering the prism decreases, hence the angle of deviation (a) of a ray of that light through the prism decreases, therefore we find:



Red light has the least angle of deviation because it has the longest wavelength and as ($n \propto \frac{1}{\lambda}$), red light encounters the least value of refractive index for the prism and the **smallest deviation.**

Violet light has the largest angle of deviation because it has the shortest wavelength and hence it has the largest refractive index and the **largest deviation.**

The dispersion of light happens distinctly when the prism is set in minimum deviation position

Thin Prism:

It is a triangular prism that is made of a transparent material (like glass) and has a very small apex angle that does not exceed 10° and it is always in the position of minimum deviation

Some concepts related to the thin prism

1. Deviation angle
2. Angular dispersion
3. Dispersive power

1- Deviation angle

Deducing the deviation angle in the thin prism:

∵ The thin prism is always in the position of minimum deviation when it is surrounded by air.

∴ When the thin prism is surrounded by air, the refractive index (n) of its material can be determined from the relation:

$$n = \frac{\sin\left(\frac{\alpha_0 + A}{2}\right)}{\sin\left(\frac{A}{2}\right)}$$

∵ $\frac{\alpha_0 + A}{2}$, $\frac{A}{2}$ are smaller angles, then the sine of these angles is approximately equal to their angles in radians.

$$\therefore\ n = \frac{\frac{\alpha_0 + A}{2}}{\frac{A}{2}} = \frac{\alpha_0 + A}{A} \quad \text{so} \quad \boxed{n = \frac{\alpha_0 + A}{A}}$$

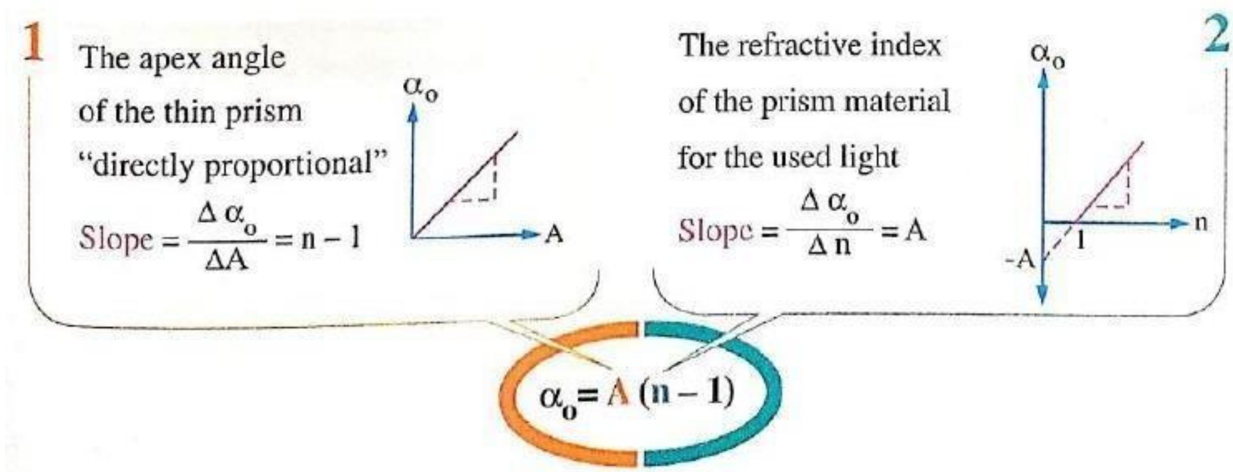
Notice that the ratio between the angles in radians equals the ratio between them in degrees.

$$\alpha_0 + A = An \qquad\qquad \therefore\ \alpha_0 = A\,(n-1)$$

When the thin prism is put in any other medium other than air, the angle of deviation will be determined from the relation:

$$\boxed{\alpha_0 = A\left(\frac{n_{prism}}{n_{medium}} - 1\right)}$$

The factors on which the angle of deviation (α_o) in the thin prism depends (when the prism is in air):



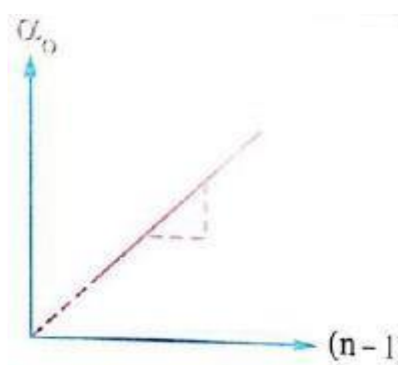
<u>Notes:</u>

(1) α_o in the thin prism doesn't depend on the first angle of incidence and it doesn't exceed 10^0

(2) The angle of deviation in the thin prism depends on the wavelength of incident light (λ)

(3) When plotting a graph of deviation angle (α_o) for multiple thin prisms that have equal apex angles versus (n -1), the opposite graph will be obtained where: **180**

Slope = $\frac{\Delta \alpha_0}{\Delta(n-1)}$ = $\mathbf{A}$



(4) To convert the value of an angle from degrees into radians and vice versa, we use the following relation $\boxed{\frac{\theta_{rad}}{\pi} = \frac{\theta_{deg}}{180}}$

And from the following table, we find that the sine of small angles ($\sin\theta$) equals approximately the values of these angles in radians (θ_{rad}):

θ_{deg}	90	60	30	10	4	1
Sin θ	1	0.87	0.5	0.1736	0.0698	0.017
θ_{rad}	1.57	1.05	0.52	0.1745	0.0698	0.017

$\theta_{\text{rad}} \approx \text{Sin}\ \theta$

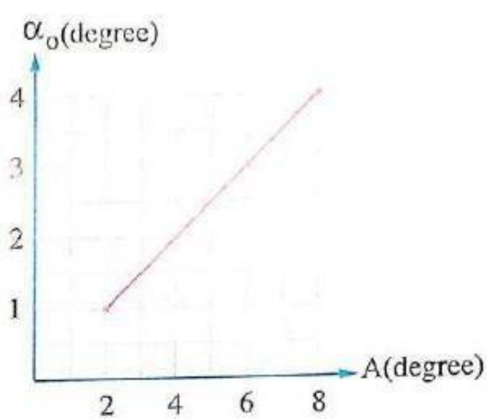
(At small angles

Example 1:

A thin prism has an apex angle of 7° and refractive index of 1.5. Calculate the angle of deviation of light in the prism.

Example 2:

The opposite graph depicts the relation between the deviation angle (α_o) of a light ray through multiple thin prisms which are made of the same material and the apex angle (**A**) for these prisms, calculate the refractive index of the material of which the prisms are made.



(a)

Before submerging the prism in the liquid

$$(\alpha_o)_1 = A\,(n-1)$$

$$4 = A\,(n-1) \quad (1)$$

After submerging the prism in the liquid

$$(\alpha_o)_2 = A\left(\frac{n}{n_{liquid}} - 1\right)$$

$$2 = A\left(\frac{n}{1.2} - 1\right) \quad (2)$$

By dividing equation (1) by equation (2):

$$\frac{4}{2} = \frac{A\,(n-1)}{A\left(\frac{n}{1.2} - 1\right)}$$

$$2\left(\frac{n}{1.2} - 1\right) = n - 1$$

$$\frac{2n}{1.2} - 2 = n - 1$$

$$\therefore n = 1.5$$

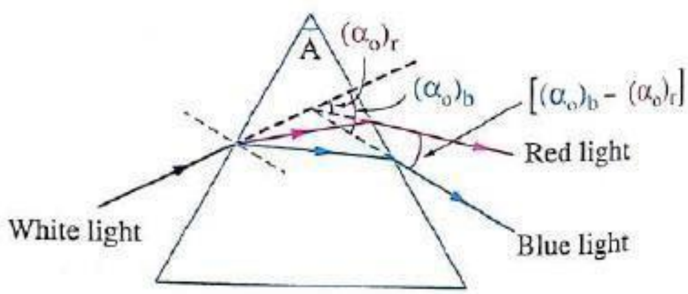
(b) By substituting with the value of n in equation (1):

$$4 = A\,(1.5 - 1) \qquad \therefore A = 8^\circ$$

2- Angular dispersion:

Deducing the angular dispersion in thin prism

The thin prism is always in the position of minimum deviation and the angle of deviation (α_o) depends on the refractive index (n) of the thin prism for the falling light ray which in turn depends on the wavelength (λ) of the falling light ray.



The angle of deviation (α_0) of the light ray changes by changing the wavelength (λ) of the ray, so the thin prism disperses the white light into the visible spectral colors, where we can determine:

① The angle of deviation of the red light	② The angle of deviation of the blue (violet) light
(the least angle of deviation for the colors of visible light)	(the largest angle of deviation for the colors of visible light)

From the relation

$(\alpha_o)_r = A(n_r - 1)$ ①

$(\alpha_o)_b = A(n_b - 1)$ ②

Where

(n_r) is the prism's refractive index for red light

(n_b) is the prism's refractive index for blue light

$\because n_b > n_r \qquad \therefore (\alpha_o)_b > (\alpha_o)_r$

By subtracting the two previous equations ① and ②, we get the value of the angle between the two emergent rays (blue and red): $(\alpha_o)_b - (\alpha_o)_r = A(n_b - 1) - A(n_r - 1)$

$$\therefore \boxed{(\alpha_o)_b - (\alpha_o)_r = A(n_b - n_r)}$$

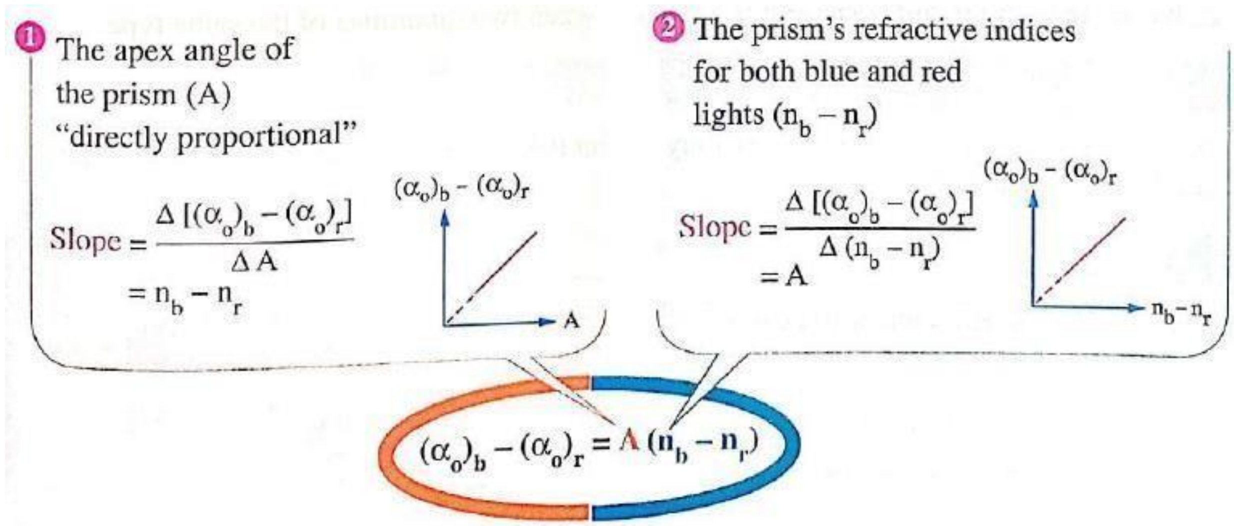
The value $[(\alpha_0)_b - (\alpha_0)_r]$ is called the angular dispersion between the blue and the red rays.

The angular dispersion:

It is the angle between the extensions of the red and blue rays after their emergence from the thin prism.

Or it is the difference between the deviation angles of red and blue lights in the thin prism.

The factors on which the angular dispersion depends:



Note: Yellow light is considered the intermediate between the blue and red lights, so we can define:

The average refractive index (n_y):	The average angle ot deviation $(a_0)_y$:
It is the refractive index of yellow light (n_y).	It is the angle of deviation of yellow light $(a_0)_y$
$n_y = \frac{n_b + n_r}{2}$	$(a_0)_y = \frac{(a_0)_b + (a_0)_r}{2}$

3- Dispersive power:

Each transparent material if shaped as a thin prism have a characteristic dispersive power that distinguishes a material from another and it can be defined as follows:

The dispersive power (ωa):

It is the ratio of the angular dispersion between blue and red lights to the angle of deviation for the yellow light (the average angle of deviation)

Deducing the Dispersive Power

$(a_0)_b - (a_0)_r$ = $A(n_b - n_r)$, $(a_0)_y$ = $A(n_y - 1)$

$$\therefore \omega a = \frac{(a_0)_b - (a_0)_r}{(a_0)_y} = \frac{A(n_b - n_r)}{A(n_y - 1)}$$

$$\boxed{\omega a = \frac{(n_b - n_r)}{(n_y - 1)} = \frac{(n_b - n_r)}{\left(\frac{(n_b + n_r)}{2} - 1\right)}}$$

Where: (n_y) is the refractive index of the prism for yellow.

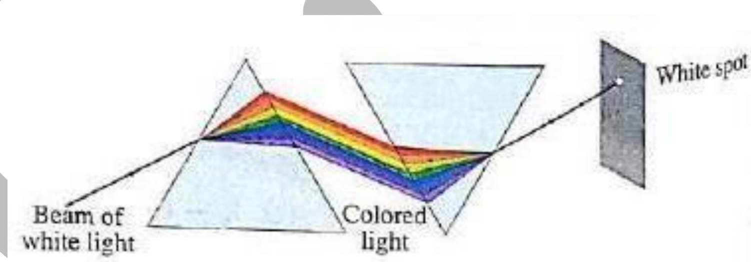
Notice that dispersive power (ωa) is dimensionless

i.e., has no measuring unit because it is a ratio between two quantities of the same type.

The factors on which the dispersive power of a thin prism depends:

It depends on the prism's material refractive index only not on the apex angle of the prism nor the light angle of incidence on it.

Note: A rectangular glass block does not disperse light because it acts as two similar reversed triangular prisms; one Counter acts the dispersion of the other.



Example1:

A thin prism has an apex angle of 8^o, its refractive index for the red light is 1.52 and its refractive index for blue light is 1.54, calculate:

a) The angle of deviation for each light color.

b) The angular dispersion for the light in the prism.

c) The dispersive power of the prism.

Example 2:

Two thin prisms have equal angular dispersions, the first prism is made of flint glass of average refractive index 1.6 and dispersive power 0.036, while the second prism is made of crown glass of average refractive index 1.5 and dispersive power 0.028. If the apex angle of the second prism is $7°$, calculate the apex angle of the first prism ($\boldsymbol{A_1}$).

From the previous, we can compare between the normal prism and the thin prism as follows:

	The normal prism	The thin prism
The apex angle(A)	Large (more than 10°)	Small (less than 10°)
The refractive index (n)	$n = \frac{\sin \varnothing_1}{\sin\theta_1} = \frac{\sin \theta_2}{\sin\varnothing_2}$	$n = \frac{a_0 + A}{A}$
The angle of deviation (a)	$a = \varnothing_1 + \theta_2 - A$	$a_0 = A\,(n-1)$ Always at the minimum deviation angle
The minimum deviation position	One of the positions at which the triangular prism can be set in which its refractive index is given by: $n = \frac{\sin\left(\frac{a_0 + A}{2}\right)}{\sin\left(\frac{A}{2}\right)}$	Always in the position of minimum deviation where the angle of deviation is determined from: $a_0 = A\,(n-1)$
Uses	-Spectral dispersion of light into its components of wavelengths. - As a reflecting prism in some optical devices such as periscope and binocular.	Dispersion of light into its components of wavelengths.

Exercise (7)

Choose the correct answer:

1) When the prism is being in the minimum deviation position, the refractive index of the prism is determined from the relation...........

a) n = $\frac{Sin\emptyset_1}{Sin\theta_2}$ b) n = $\frac{Sin\emptyset_1}{Sin\emptyset_2}$ c) $\frac{Sin(\frac{\alpha_0+A}{2})}{Sin}$ d) n = $\frac{Sin\ A}{Sin\ \alpha}$

2) The deviation angle for a light ray that passes through an equilateral triangular prism in the minimum deviation position is 30°, then:

(i) The angle of incidence of the ray on the prism face equals …………

a) 30° b) 45° c) 60° d) 90°

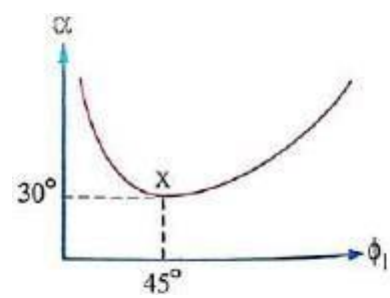
ii) The emergence angle of the ray from the prism equals

a) 90° b) 60° c) 45° d) 30°

3) A triangular prism has an apex angle of 60° and a refractive index of $\sqrt{2}$, then the angle of deviation and the angle of incidence at the minimum deviation position respectively are.

a) 30°,45° b)45°, 30° c) 60°,45° d)45°,60°

4) The opposite graph shows the relation between the angle of a deviation (α) and the first angle of incidence ($\emptyset_1$) for a light ray on one of the faces of a triangular prism, so:



(i) The apex angle of the prism equals

a) 30° b) 45° c) 60° d) 90°

ii) The absolute refractive index of the prism material equals ……………….

a) 1.5 b) $\sqrt{2}$ c) 1.33 d) $\sqrt{3}$

iii)The emergence angle of the ray at the position of x equals……………….

a) 30° b) 37° c) 45° d) 75°

5)If a light ray is incident on an equilateral triangular prism and undergoes the minimum deviation, the second angle of incidence inside the prism equals..............

a) 30° b) 45° c) 60° d) 90°

6)A glass prism in which a light ray has deviated with an angle that equals its first angle of incidence that equals 60° has an apex angle of 60°, so the refractive index of the prism's material equals …………

a) $\sqrt{2}$ b) $\frac{1}{\sqrt{2}}$ c) $\sqrt{3}$ d) $\frac{1}{\sqrt{3}}$

7) A light ray is incident on an equilateral triangular prism, if the angle of incidence= The angle of emergence = 40°, then:

(i) The angle of deviation of the light ray equals .

a) 20° b) 40° c) 60° d) 80°

ii) The refractive index of the prism's material equals …………

a) 1.1 b) 1.15 c) 1.29 d) 1.53

8) A light ray is incident with an angle ($Ø_1$) on one of the faces of an equilateral triangular prism, hence it gets refracted by an angle of 30°, what happens to the deviation angle of the light ray (α) when increasing or decreasing the angle of incidence ($Ø_1$) by 5°?

	Increasing ($Ø_1$)	Decreasing ($Ø_1$)
a)	Deviation increases	Deviation decreases
b)	Deviation increases	Deviation increases
c)	Deviation decreases	Deviation decreases
d)	Deviation decreases	Deviation increases

9) The ratio between the refractive index of the material of a triangular prism for violet light and the refractive index of the material of the same prism for red light ($\frac{n_{violet}}{n_{red}}$) is ....

a) greater than one

b) less than one

c) equal to one

d) indeterminable

10) On increasing the wavelength of an incident light ray on one of the faces of a triangular prism in minimum deviation position, the minimum deviation angle..............

a) increases

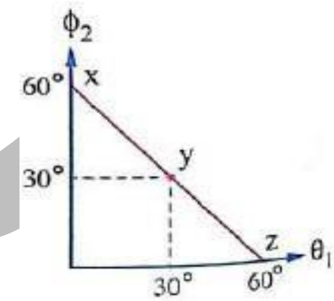
b) decreases

c) doesn't change

d) cannot be determined

11) The opposite graph shows the relation between the second angle of incidence (ϕ_2) and the first angle of refraction (θ_1) of a light ray falling into a triangular prism. If the angle of minimum deviation is 30°, so:

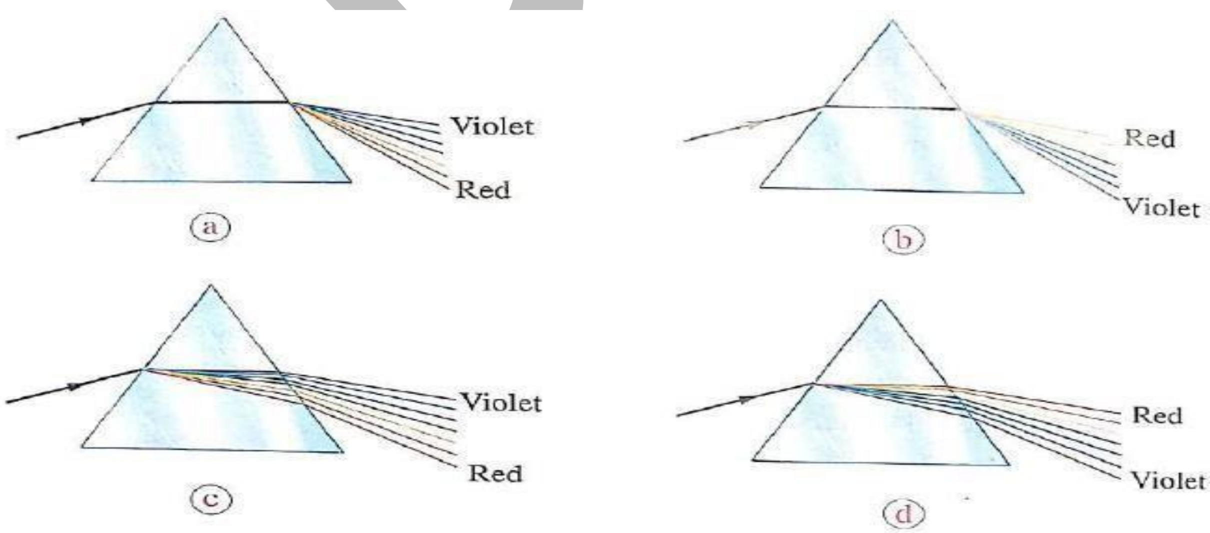
The refractive index of the prism equals



a) $\sqrt{2}$ b) 1.48

c) $\sqrt{3}$ d) 1.55

12) If a narrow beam of white lights falls on one of the faces of a triangular prism set in the minimum deviation position, which of the following figures shows how this beam of light disperses?



13) A thin prism with an apex angle of 8° refractive index for red light 1.4 and for blue light 1.6, then the average angle of deviation for white light through it equals…………

a) 16° b) 12° c) 8° d) 4°

2) Essay questions: (explain the following)

1In the same triangular prism the angle of minimum deviation changes by the change of the wavelength of the passing light through it.

………

………

2When white light falls on a triangular prism, the deviation of the violet light will be greater than that of the red light.

………

………

3Triangular prisms disperse white light while the transparent cuboid slabs don't.

………

………

- What happens when a beam of white light falls on a triangular prism adjusted in the minimum deviation position?

………

………

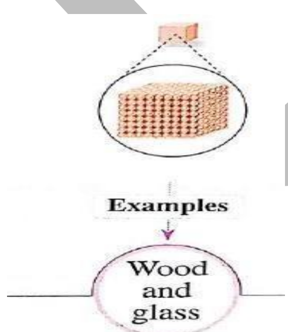
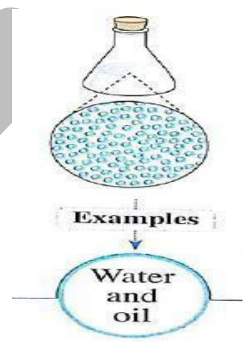
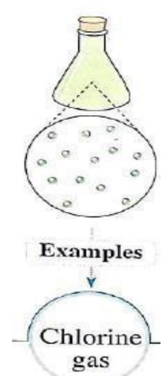
………

Chapter 4

Lesson 1: Fluid Flow

The states of matter:

You have studied in the previous years that matters can be found in one of three states:

Solid	Liquid	Gas
Its molecules are tightly packed (the spaces between them are very small) and they are locked into their places in a regular pattern, so the solids have definite shape and volume.	Its molecules are close together with no regular arrangement and they can move and slide past each other, so a liquid doesn't have a definite shape and it takes the shape of its container, so it is called a fluid.	Its molecules are separated by relatively large spaces with no regular arrangement and they move freely at high speeds, so a gas doesn't have a definite shape but it takes the shape of its container, so it is called a fluid.
		

From the previous, a fluid can be defined as follows:

A fluid:

It is a material that can flow and has no definite shape. Like liquids and gases.

In this chapter, we will study only two of the properties of the moving fluids which are:

1- Flow **2- Viscosity**

And in this lesson, we will study the flow of liquids in some detail.

Flow:

The flow of liquids are classified into two types:

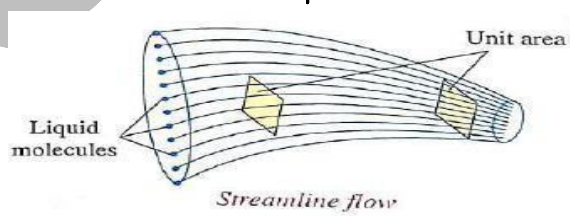
a) Steady flow b) Viscosity

a) Steady flow

When a liquid moves such that its adjacent layers slide smoothly over each other, we describe this motion as a laminar flow or a streamline (steady) flow, where every small amount of the liquid follows a continuous imaginary path called streamline.

Characteristics of streamlines:

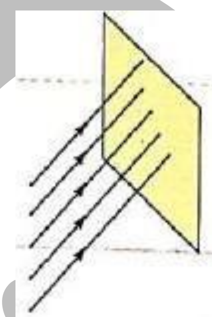
1) They are imaginary lines that do not intersect.
2)The number of streamlines at any cross-section of the tube is constant.
3) The direction of the instantaneous velocity (v) of a small amount of a liquid at a certain point along a streamline is determined by the tangent of that streamline at that point



4. The flow speed of a liquid at a point is determined by the density of streamlines at that point, so the speed of fluid flow increases by increasing the density of streamlines at that point and decreases by decreasing the density of streamlines.

Density of streamlines at a point:

It is estimated by the number of streamlines that pass Perpendicularly through a unit area surrounding that point.



Conditions of steady flow :

1.The speed of the liquid at one given point along the path of the liquid remains constant and does not change as time passes.

2. The flow is irrotational ,i.e. there is no vortex motion.

3. No frictional forces exist between the layers of the liquid.

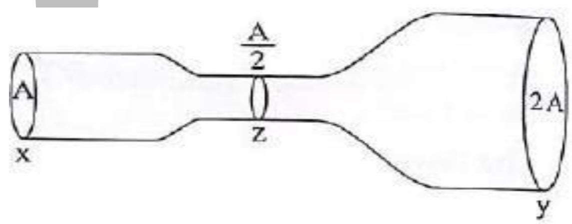
4.The flow rate of the liquid should be constant along its path because the liquid is incompressible and its density does not change with distance or time.

5.The liquid fills the tube completely such that the amount of liquid (volume and mass) that enters the tube at one end equals the amount of liquid that emerges from the other end in the same time interval according to the law of mass conservation.

Example 1:

The opposite figure shows a liquid flowing steadily in a tube from one terminal to the other, so the ratio of the numbers of streamlines through the cross-sections x:y:zis ....

a) 2 : 1 : 4 b) 1 : 2 : 4
c) 2 : 4 : 1 d) 1 : 1 : 1



Solution

In the steady flow, the number of streamlines through any cross-section of the tube remains constant where the streamlines don't intersect.

So the correct choice is d)

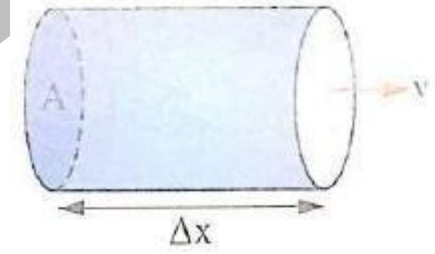
Density (ρ):

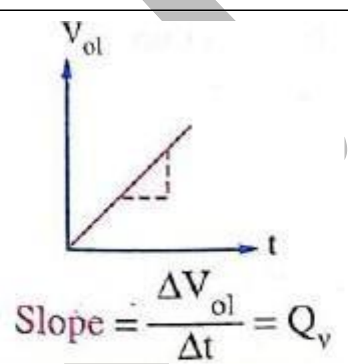
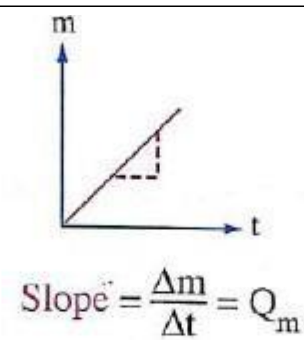
It is the mass of a unit volume of the material. It is measured in kg/m^3 and calculated from the relation:

$$\rho = \frac{m}{V_{ol}}$$

Flow rate

Consider a quantity of volume (V_{ol}) and mass (m) of a liquid of density(ρ) flowing through a cross-sectional area of a tube (A) at velocity (v), where it covers a distance Δx in time Δt as in the figure, then:



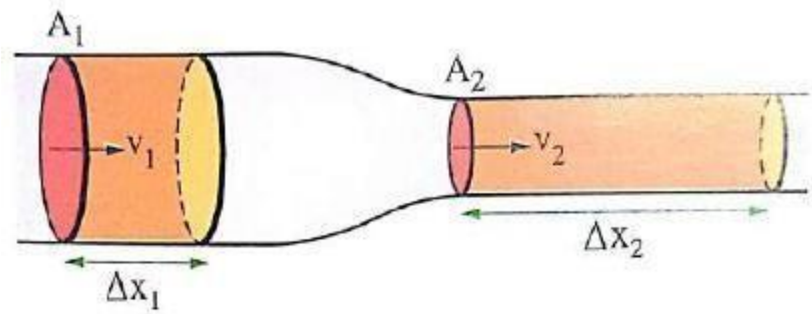
	Volume flow rate (Q_V)	Mass flow rate (Qm)
Concept	The volume of liquid that flows steadily through a definite cross-section of a tube in one second.	The mass of liquid that flows steadily through a definite cross-section of a tube in one second.
Deducing the relation	$V_{ol} = A * \Delta x$ $Q_V = \frac{Vol}{\Delta t} = A \frac{\Delta x}{\Delta t}$ $\boxed{Q_V = A * v}$	$m = \rho * Vol$ $m = \rho * A * \Delta x$ $Q_m = \frac{m}{\Delta t}$ $= \rho * A * \frac{\Delta x}{\Delta t}$ $\boxed{Q_m = \rho * A * v}$
	So $\boxed{Q_m = \rho * Q_V}$	
Measuring unit	m^3/s	Kg/s
Graphical representation		

From the previous, we conclude that:

When the liquid flows steadily across a tube, the flow rate (volume or mass) will be constant at any cross-section of the tube.

<u>Deducing continuity equation (the relation between the liquid flow speed and the cross – sectional are of the tube:</u>

Assume two different cross-sections of a tube that contains a liquid of density(ρ), flowing steadily as in the following figure:



In the first cross-section (A1)	In the second cross-section (A2)
<u>The volume flow rate</u>	
$Q_V = A1 * v1$	$Q_V = A2 * v2$
<u>The mass flow rate</u>	
$Q_m = \rho * A1 * v1$	$Q_m = \rho * A2 * v2$

∵ The liquid flows steadily.

∴ The flow rate (volume or mass) is constant at any cross-section of the tube.

∴ $\rho * A1 * v1 = \rho * A2 * v2$ ∴ $A1 * v1 = A2 * v2$

∴ $\boxed{\frac{v1}{v2} = \frac{A1}{A2}}$ this relation is called the continuity equation.

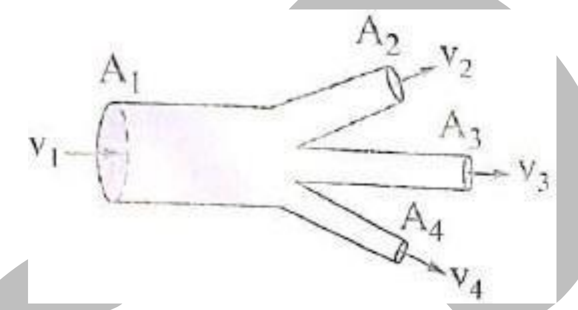
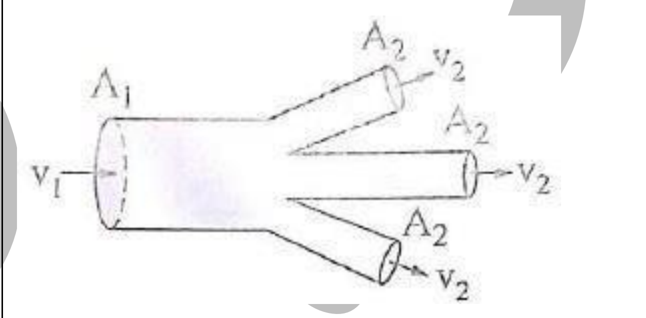
∴ $A = \pi r^2$, where r is the radius of the tube cross-section.

∴ $\boxed{\frac{v1}{v2} = \frac{r_2^2}{r_1^2} = \frac{d_2^2}{d_1^2}}$ where d is the diameter of the tube cross-section.

From the previous, we can conclude that:

The speed of liquid that is flowing steadily in a tube at any point is inversely proportional to the cross-section area of the tube (as well as the square of the radius of the tube and also the square of its diameter) at that point.

<u>When the liquid flows steadily in a tube that branches into a number of branches of:</u>

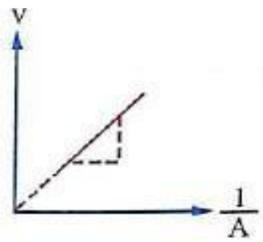
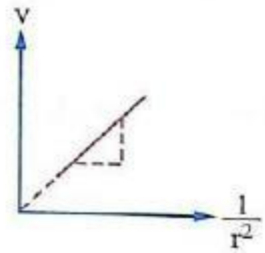
Different cross-sectional areas	The same cross-sectional area
	
Then	
$A_1v_1 = A_2v_2 + A_3v_3 + A_4v_4$	$A_1v_1 = nA_2v_2$ (where n is the number of branches)
$r_1^2 v_1 = r_2^2 v_2 + r_3^2 v_3 + r_4^2 v_4$	$r_1^2 v_1 = n\, r_2^2 v_2$
$d_1^2 v_1 = d v_2 + d_3^2 v_3 + d_4^2 v_4$	$d_1^2 v_1 = n\, d_2^2 v_2$

<u>Notes:</u>

1) When a liquid flows steadily in a tube of non-uniform cross-sectional area, we can represent the graphical relation between:

a) Velocity of the liquid(v) and reciprocal of the cross-sectional area($\frac{1}{A}$)

b) Velocity of the liquid (v) and reciprocal of square of the cross-sectional radius ($\frac{1}{r^2}$)

Velocity of the liquid (v) and reciprocal of the cross-sectional area $(\frac{1}{A})$	Velocity of the liquid (v) and reciprocal of square of the cross-sectional radius $(\frac{1}{r^2})$
 $\text{Slope} = \frac{\Delta v}{\Delta\left(\frac{1}{A}\right)} = Q_v$	 $\text{Slope} = \frac{\Delta v}{\Delta\left(\frac{1}{r^2}\right)} = \frac{Q_v}{\pi}$

2) When opening multiple taps together to fill a container with a liquid such that the flow rate of the liquid from each tap is $(Q_V)_1$,$(Q_V)_2$, $(Q_V)_3$,then the total flow rate (Q_V) of filling the container is calculated from the relation : $\boxed{Q_V = (Q_V)_1 + (Q_V)_2 + (Q_V)_3}$

(3) When a liquid flows steadily in a tube, then at any cross-section of the tube;

Q_v (Volume flow rate)

$$Q_v = Av = \pi r^2 v = \frac{Q_m}{\rho} = \frac{V_{ol}}{t} = \frac{m}{\rho t}$$

(4) When a liquid flows in a tube with two different cross-sectional area;

To compare the liquid flow at both cross-sections

- $(Q_v)_1 = (Q_v)_2$
- $(Q_m)_1 = (Q_m)_2$
- $A_1 v_1 = A_2 v_2$
- $r_1^2 v_1 = r_2^2 v_2$
- $d_1^2 v_1 = d_2^2 v_2$

Example 1:

Water flows from a water tap in the rate of 0.5 kg/s, so the time required to fill a container of volume 2 m^3 using this tap is............

(Where ρ_{water} = **1000 Kg/m^3**)

a) 10^3 s b) 4×10^3 s c) 10^4 s d) 4×10^4 s

Solution: $Q_m = 0.5$ kg/s $V_{ol} = 2\ m^3$ $\rho_{water} = 1000\ Kg/m^3$ t =??

$$V_{ol} = Q_v\, t \qquad \text{so} \quad t = \frac{V_{ol}}{Q_v} = \frac{V_{ol} * \rho}{Q_m} = \frac{2 \times 1000}{0.5} = 4 \times 10^3\ s$$

Example 2:

The opposite figure shows a water container of volume V_{ol}, which can be filled using two water taps x and y such that if only tap x is used, the container takes 15 minutes to be filled but if only tap y is used, the container takes 30 minutes to be filled, then the time required to fill the container by using the two taps x and y together is

a) 5 minutes b) 10 minutes c) 15 minutes d) 20 minutes

Solution: t_x = 15 minutes t_y = 30 minutes t = ???

$$Q_v = Q_{vx} + Q_{vy} \qquad , \qquad Q_v = \frac{V_{ol}}{t}$$

$$\frac{V_{ol}}{t} = \frac{(V_{ol})_x}{t_x} + \frac{(V_{ol})_y}{t_y}$$

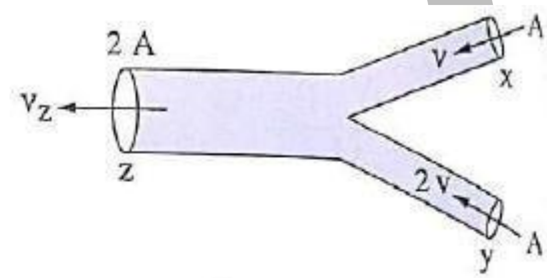
But the Volume (V_{ol}) of container is fixed.

$$\frac{1}{t} = \frac{1}{t_x} + \frac{1}{t_y} \qquad \frac{1}{t} = \frac{1}{15} + \frac{1}{30} = \frac{1}{10}$$

So **t = 10 minutes**

<u>Example 3:</u>

A liquid flow steadily in a tube as the opposite figure. If the cross-sectional area of x, y, z are **A**, **A**, **2A** respectively and the liquid speeds at the cross-section x, y are **v, 2v** respectively, then the liquid speed at z equals …………



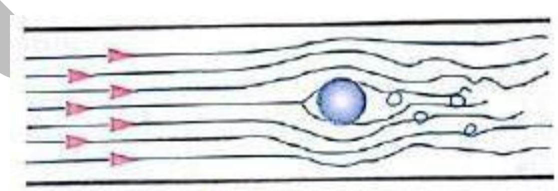
A) 2v b) $\frac{2}{3}$ v c) $\frac{3}{2}$ v d) v

<u>Turbulent Flow:</u>

The flow of fluid becomes turbulent which is characterized by the presence of small eddy currents forming vortices as in the figure when:

-The speed of the fluid exceeds a certain limit.

-A gas transfers from small space to a wider space or from high pressure to low pressure



Eddy currents

Turbulent flow of the smoke

Exercise (8)

Choose the correct answer:

1) In steady flow, when the cross-sectional area of the tube decreases, the density of streamlines ………

a) increases b) decreases but doesn't reach zero
c) vanishes d) remains unchanged

2)The number of streamlines of a liquid which passes perpendicularly through a unit area surrounding a certain point indicates ………

a) the liquid speed at that point b) the volume flow rate
c) the mass flow rate d) the liquid density

3)In the opposite figure, a liquid flow steadily in a tube, so the physical quantity which is greater a cross-section x than at cross-section y is ….

a) the liquid speed
b) the volume of the flowing liquid in unit time
c) the mass of the flowing liquid in unit time
d) the number of the streamlines through the cross-section

4)Water flows steadily in a tube of diameter 2 cm at a speed of 5 m/s. Thus;

(i) The volume of water which is flowing through the cross-section of the tube in one-minute equals ………. (where π=3.14)

a) 9.42 m^3 b) 0.19 m^3 c) 0.0942 m^3 d) 0.001 m^3

(ii) The time required to fill a tank of volume 20m^3 by using the flowing water from the tube is …….

a) 127.38 minutes c) 3.54 minutes
b) 212.31 minutes d) 2.123 minutes

5) A water pipe has cross-sectional area 4cm^2 at the ground floor and 2cm^2 at the upper floor. If water is flowing steadily inside the pipe such that its speed at the ground floor was 2m/s, then:

(Given that: Water density = 1000 kg/m^3)

(i) The flow speed at the upper floor is .....

a) 1 m/s b) 2 m/s c) 3 m/s d) 4 m/s

(ii) The volume flow rate of water at the ground floor equals ....

a) 4×10^{-4} m^3/s b) 6×10^{-4} m^3/s c) 8×10^{-4} m^3/s d) 12×10^{-4} m^3/s

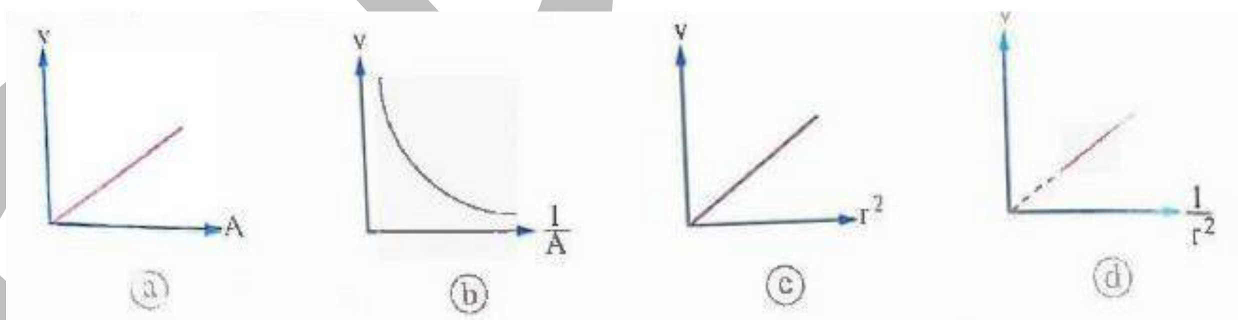
(iii) The mass flow rate of water at the upper floor equals........

a) 1.2kg/s b) 0.8kg/s c) 0.6kg/s d) 0.4kg/s

6) Water is rushing through a pump opening of cross-sectional area 5 cm^2 at a speed of 12m/s. The mass of water coming out from the pump within 30 minutes is.......... (Given that: Density of water = 1000 kg/m)

a) 18.2×10^3kg b) 15.1×10^3kg c) 10.8×10^3kg d) 8.6×10^3kg

7) The graph that represents the continuity equation for liquids flow is ....



8) Oil flows in a tube x at a rate of 6 liters/minute and gets out from another tube y which is connected to the first tube x at a speed of 4m/s, then the cross-sectional area of the second tube y equals ....

a) 1.5×10^{-3} m^2 b) 1.5 m^2 c) 2.5×10^{-5} m^2 d) 0.025 m^2

9) If the cross-section of a tube has increased to the double in steady flow, then the flow speed ....

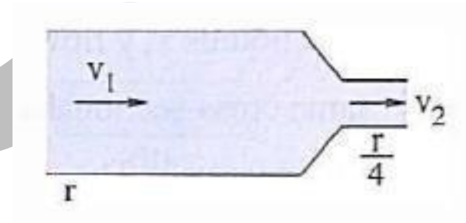
a) gets doubled b) decreases to half its value

c) gets quadrupled d) remains constant

10) If the ratio between the radii of two cross-sections of a tube in steady flow is $\frac{1}{2}$ then the ratio between the speeds of the liquid through them respectively is …………….

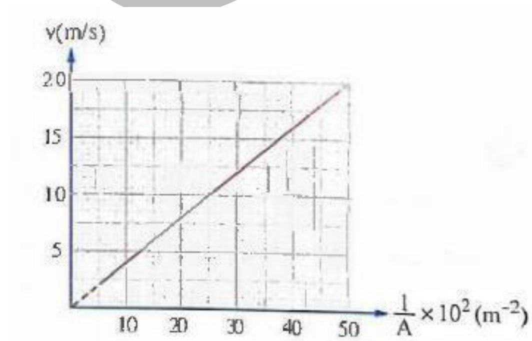
a) $\frac{1}{4}$ b) $\frac{1}{2}$ c) $\frac{2}{1}$ d) $\frac{4}{1}$

11) A liquid flows steadily in a tube that tapers from radius r at one end to radius $\frac{r}{4}$ at the second end as in the opposite figure, then the ratio between the speed of the liquid in the first cross-section of the tube and its speed in the second cross-section of the tube equals..........



a) $\frac{1}{4}$ b) $\frac{1}{16}$ c) $\frac{16}{1}$ d) $\frac{4}{1}$

12) The opposite graph illustrates the relation between the liquid flow speed (v) at a point in a tube and the reciprocal of the cross-sectional area of the tube ($\frac{1}{A}$) at that point, then:



(i) The volume flow rate equals …………

a) $40 m^3/s$ b) $4 m^3/s$

c) $0.4 m^3/s$ d) $0.004 m^3/s$

(ii) The mass of the flowing liquid within 30 minutes if the liquid density is 1000 kg/m^3 equals ....

a) 120 kg b) 1200 kg c) 7200 kg d) 7.2×10^5 kg

13) An oil pump pumps $1.2 m^3$ of oil within 60s in a cylindrical tank of diameter 4m and height 3m. If the oil density is 820 kg/m^3, then:

(i) The mass flow rate of the oil from the pump opening equals .... a) 0.02kg/s b) 5.2kg/s c) 16.4kg/s d) 18.4kg/s

(ii) The time required to fill the tank with oil is ……….

a) 27.21 minutes b) 31.43 minutes

c) 42.43 minutes d) 51.54 minutes

Chapter 4

Lesson 2: viscosity

Viscosity:

It is the property that causes a resistance or a friction between the liquid layers preventing them from sliding smoothly above each other.

The higher viscous liquid:

1. Shows higher resistance to its own motion and its flow.
2. Shows higher resistance to the motion of bodies through it.

Explaining the concept of viscosity:

There are two types of attraction forces between the molecules of matter:

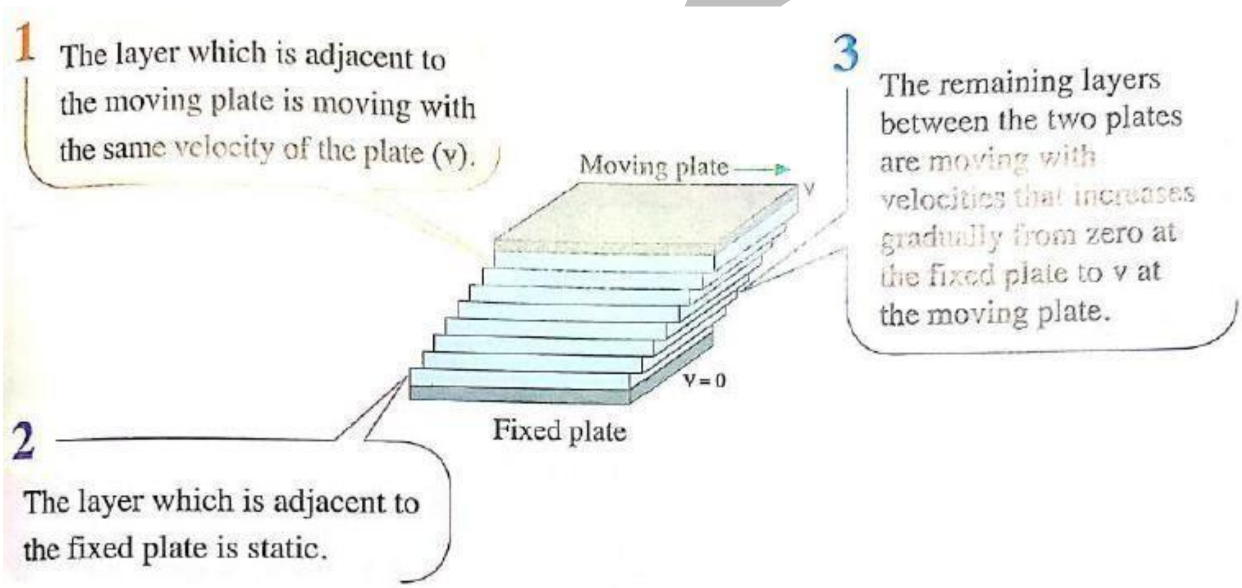
1 Cohesive forces:

Attraction forces between the molecules of the same substance like the attraction forces between the honey molecules.

2 Adhesive forces:

Attraction forces between the molecules of a substance and the molecules of another substance like the adhesive forces between the molecules of a drop of water and glass.

Imagine a quantity of a fluid confined between two parallel plates, one of them is static and the other moves with velocity (v) as shown in the figure.



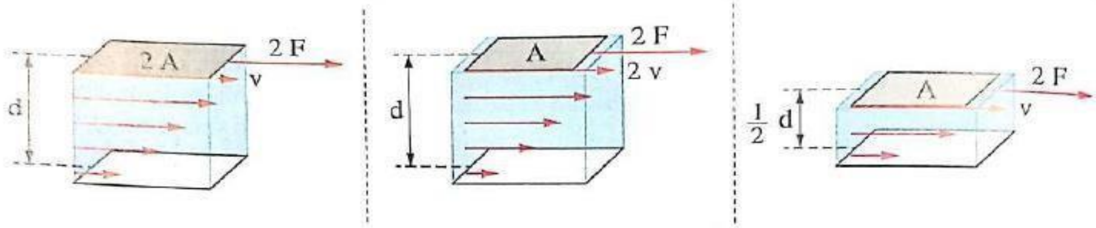
This happens due to:

1.The presence of friction between each plate and the adjacent layer of liquid that results from the adhesive forces between the molecules of the solid plate and the molecules of the adjacent liquid layer, so the speed of every layer is equal to that of its adjacent plate.

2.The existence of another force between each liquid layer and the layer below it which resists the sliding of the liquid layers above each other causing a relative change in velocity between each layer and the adjacent layer.

This type of flow is called **<u>the laminar flow</u>** or **<u>viscous flow</u>**

1. Directly proportional to the area of the moving layer ($F \propto A$)
2. Directly proportional to the velocity difference between the two layers ($F \propto v$)
3. Inversely proportional to the perpendicular distance between the two layers ($F \propto \frac{1}{d}$)



$\therefore F \propto \frac{Av}{d}$

$\therefore F = \text{constant} \times \frac{Av}{d}$

$\therefore \boxed{F = \eta_{vs} \frac{Av}{d}}$

$\therefore \boxed{\eta_{vs} = \frac{Fd}{Av}}$

Where: η_{vs} is the viscosity coefficient that can be defined as:

Viscosity coefficient (η_{vs}):

It equals numerically the tangential force that acts upon a unit area of a liquid causing a velocity difference of one unit between two layers separated by a perpendicular distance of one unit.

The measuring unit of **Viscosity coefficient** is $N.s/m^2$ that is equivalent to $kg/m.s$ Or $J.s/m^3$

The factors affecting the viscosity coefficient :

1. **Type of the liquid**
2. **Temperature of the liquid (The liquid viscosity decreases as its temperature increases)**

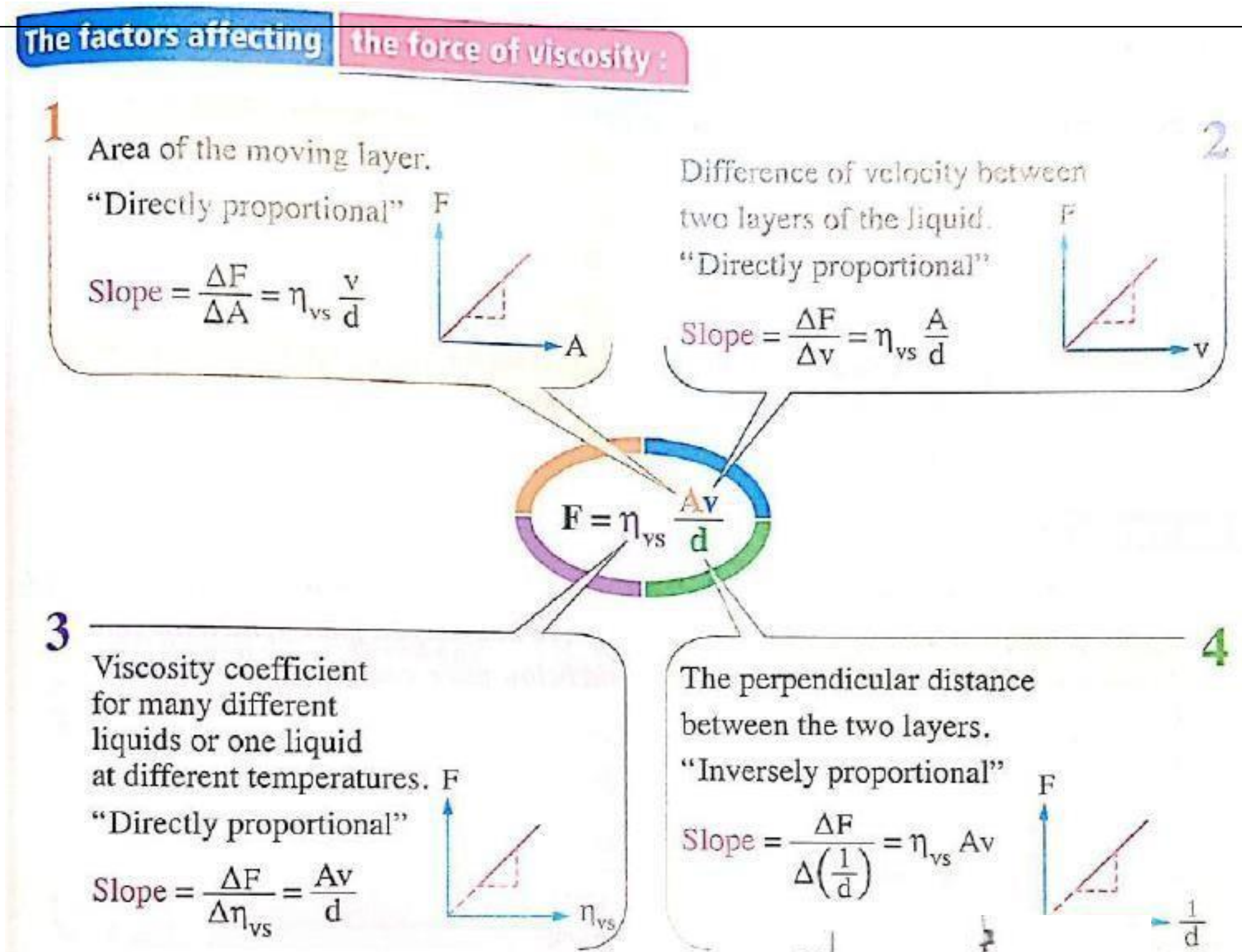
Examples

At temperature 20°C:

- $(\eta_{vs})_{water} = 10^{-3}\ N.s/m^2$
- $(\eta_{vs})_{glycerin} = 1.5\ N.s/m^2$
- $(\eta_{vs})_{honey} = 10\ N.s/m^2$

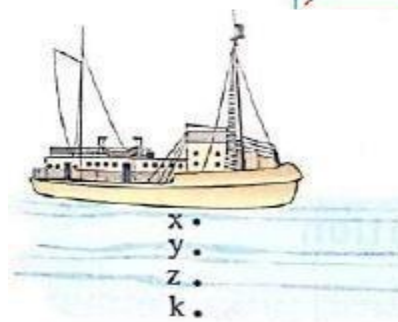
Viscosity coefficient of water at temperature:

- $t = 20°C \Rightarrow \eta_{vs} = 10^{-3}\ N.s/m^2$
- $t = 100°C \Rightarrow \eta_{vs} = 1.227 \times 10^{-5}\ N.s/m^2$



Example 1:

In the opposite figure a ship moves in a still water lake, so the water speed is less at point…………………



a) x　　b) y

c) z　　d) k

Example 2:

A plane surface of area 0.5 m² moves at a uniform velocity of 2 m/s parallel to another static surface that is separated from it by a layer of liquid of thickness 4 cm, if the viscosity coefficient of the liquid is 15 kg/m.s, then the force required to keep the surface moving with this uniform velocity is ....

a) 37.5 N　　b) 50 N　　c) 67.5N　　d) 150 N

Application of viscosity:

1- Lubrication of machines.

Machines should be lubricated from time to time to decrease the heat produced due to friction and to protect the machine parts from corrosion and increase its efficiency.

Highly viscous oils are used due to their strong adhesive forces with the machine parts, since they do not seep away or sputter from the machine parts during motion

Note:

Water cannot be used in lubrication because it has low viscosity, so it seeps away from the machine parts due to the weak adhesive force with the machine parts.

2-Saving fuel consumption in moving vehicles:

• The rate of fuel consuming in a moving vehicle depends on:

1. Motion of the vehicle with an acceleration (changing velocity).

2. Friction forces with:
- The road.
- Air (air resistance to the motion of the vehicle).

When the vehicle moves in a uniform velocity (acceleration= zero), so if this velocity is:

Low or medium	Higher than a certain limit

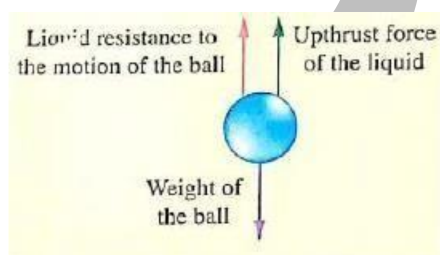
So, the expert driver of the vehicle limits the vehicle speed to reduce fuel consumption.

3In medicine, blood precipitation rate test (the terminal velocity of falling of the red blood cells in plasma)

When a ball falls freely in a liquid, it is affected by three forces:

- Its weight.
- Buoyancy (up thrust force) of the liquid.

Friction between the ball and the liquid due to viscosity.



So, the velocity of the ball increases gradually till it attains a constant terminal velocity due to the balance of these three forces. The terminal velocity increases as the radius of the ball increases, so it can be determined if the volume of the red blood cells was normal or not by taking a blood sample and measuring its precipitation rate which is proportional to the terminal velocity of the falling red blood cells in the plasma, **for example**:

When	
The precipitation rate is greater than normal	The precipitation rate is lower than normal
it indicates that	
Red blood cells adhere together, so their volume and radius increase.	Red blood cells break down, so their volume and radius decrease.
so the terminal velocity of blood cells	
becomes higher	becomes lower
Like the case of	
Rheumatic fever	Anemia

Exercise (9)

Choose the correct answer:

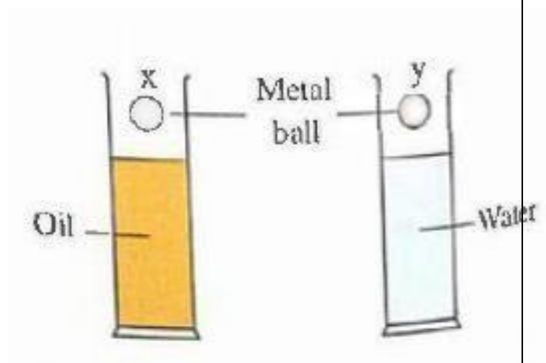
1) When a metallic ball falls through a fluid in a jar, the viscosity force of the liquid which is acting on the ball depends on ………

a) the ball radius b) the liquid density
c) the ball mass d) the liquid quantity

2) If the speed difference between two liquid layers gets decreased when a tangential force is acting on the upper layer, then at the same temperature the viscosity coefficient ………………

a) vanishes b) decreases but doesn't vanish
c) increases d) remains constant

3)The opposite figure shows two identical metal balls (x, y) falling from the same height into two identical jars containing similar volumes of oil and water till reaching the bottoms, then the average speed of ball x is.........



a) greater than the average speed of ball y
b) less than the average speed of ball y
c) equal to the average speed of ball y
d) equal to its instantaneous speed at the bottom of the jar

4)A metallic ball has fallen once through water and another time through honey, if the average frictional force between the ball and the water is F_1 and between the ball and the honey is F_2 then which of the following statements for F_1 and F_2 is correct?

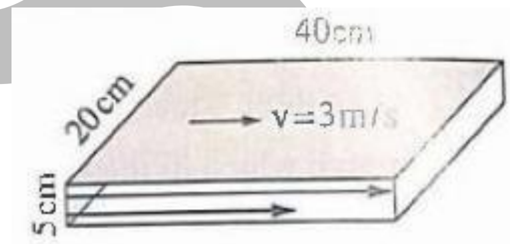
a) $F_1 = F_2 = 0$ b) $F_1 = F_2 \neq 0$

c) $F_1 > F_2$ d) $F_1 < F_2$

5)At relatively low or medium speeds of a car, the air resistance due to air viscosity is ....

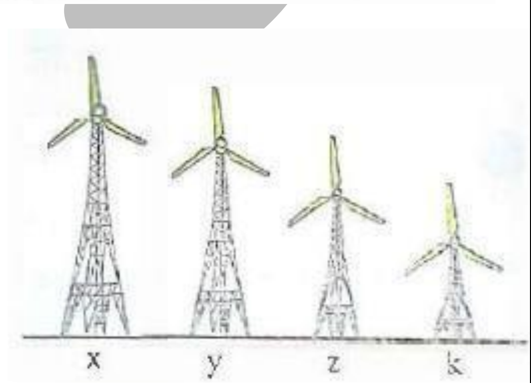
a) directly proportional to the square of the speed of the car
b) directly proportional to the speed of the car
c) inversely proportional to the square of the speed of the car
d) inversely proportional to the speed of the car

6)In the opposite figure, if a tangential force of 10 N acted upon the upper plate to move it at a uniform speed of 3 m/s, then the viscosity coefficient of the liquid equals ....



a) 0.021 N.s/m^2 b) 0.48 N.s/m^2
c) 0.75 N.s/m^2 d) 2.08 N.s/m^2

7) The opposite figure shows four windmills of identical turbines and blades installed near each other at different heights to be used for generating electricity, so the windmill that has the greater potential of generating electricity will be ....



a) x b) y
c) z d) k

8) A rectangular plate of dimensions 50 cm, 25 cm is affected by a tangential force of 15 N which moves it at a constant speed of 0.8 m/s on a layer of viscous liquid of thickness 9.375 mm, so the viscosity coefficient of the liquid is ....

a) 0.42 kg/m.s b) 0.85 kg/m.s c) 1.41 kg/m.s d) 2.31 kg/m.s